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Reviewed by: Jaromír Beneš (International Monetary Fund)
Andrew Blake (Bank of England)
Michal Franta (Czech National Bank)

Project Coordinator: Jan Babecký

Monetary Policy Implications of Financial Frictions in the Czech Republic

Jakub Ryšánek, Jaromír Tonner, and Osvald Vašíček*

Abstract

As the global economy seems to be recovering from the 2009 financial crisis, we find it desirable to look back and analyze the Czech economy *ex post*. We work with a Swedish New Keynesian model of a small open economy which embeds financial frictions in light of the financial accelerator literature. Without explicitly modeling the banking sector, this model serves as a tool for understanding how a negative financial shock may spread to the real economy and how monetary policy may react. We use Bayesian techniques to estimate the model parameters to adjust the model structure closer to the evidence stemming from Czech data. Our attention focuses on a set of experiments in which we generate *ex post* forecasts of the economy prior to the 2009 crisis and illustrate that the monetary policy response to an upcoming crisis implied by the model with financial frictions is stronger on account of an increasing interest rate spread.

JEL Codes: C53, E32, E37.

Keywords: Bayesian methods, financial frictions.

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* Jakub Ryšánek (corresponding author): Faculty of Informatics and Statistics, University of Economics, Prague, and Macroeconomic Forecasting Division, Czech National Bank (jakub.rysanek@cnb.cz); Jaromír Tonner: Faculty of Economics and Administration, Masaryk University, and Macroeconomic Forecasting Division, Czech National Bank (jaromir.tonner@cnb.cz); Osvald Vašíček: Faculty of Economics and Administration, Masaryk University (osvald@econ.muni.cz).

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Nontechnical Summary

The fall of Lehman Brothers, once a U.S. banking giant, in September 2008 became a symbol of the American credit crisis. The unfavorable situation in the mortgage market spilled over to other parts of the U.S. economy and sent international financial markets into financial distress. Based on traditional ratings, it was no longer possible to distinguish sound banks from those owning a large share of toxic assets. As a consequence, interbank liquidity flows decreased massively. The general uncertainty and the reluctance of banks to provide credit resulted in an economic downturn in many countries, some of which are still struggling with negative numbers. In an effort to loosen the monetary conditions, central banks did not hesitate long before lowering interest rates. Apart from that, demand for stricter banking supervision and regulation led to revisions of the banking regulatory standards – the newly established Basel III Accord will become effective in 2013.

Specifically, in the case of the Czech Republic, the financial crisis hit the economy via a slump in foreign demand. Not surprisingly, the lowered policy rates were not entirely transmitted into market rates. These remained at pre-crisis levels and banks were not willing to loosen their credit conditions since they needed to compensate for increasing default rates at that time.

This increased interest rate spread is one of the key factors weakening the effectiveness of monetary policy in reviving the economy. Understanding the implications of financial frictions for economic dynamics is the main focus of this paper. We try to explain recent events by relying on a model of the Swedish economy as proposed by Christiano *et al*. (2011), which assumes financial frictions in the bank lending channel besides the traditional standard macroeconomic channels, of which the exchange rate matters the most in the case of a small open economy. First, we adjust the model structure to fit the Czech specifics. Second, we estimate the model using Bayesian techniques. The traditional output of the Bayesian calculations is presented in a separate appendix. Lastly, we describe the dynamics of the model as a response to a financial shock and carry out a pair of forecast exercises with a history fixed prior to the economic crisis of 2009 to reveal the differences in forecasting behavior between the model with and without a financial frictions block and the CNB's g3 model conditional on the outlook of the foreign variables. The structures of these models overlap each other very much. Both models assume an open economy setting, contain a complete system of the national accounts and use different variants of uncovered interest rate parity conditions augmented by a risk premium. The main difference is that the g3 model does not contain an explicit block of the financial frictions.

Our results suggest that the inclusion of the financial frictions into the model mechanism implies faster lowering of the interest rates prior to the 2009 crisis. The g3 model also indicates cutting of the interest rates in this period, however, due to other than financial factors. Furthermore, the effect of financial frictions on economic fluctuations does not stay constant over time and its macroeconomic implications are naturally the most significant during periods of high interest rate spreads while its implications are limited at times when the interest rate spreads are relatively low. This can be best seen from the shock decomposition of relevant endogenous variables, as financial shocks do not dominate in contribution for the most of the time, but increase in magnitude hand in hand with the economic crisis of 2009. This is especially the case for real investment together with real imports, due to the fact that most investment is imported into the Czech Republic.

The potential use of this paper in policy analysis is twofold. First, the forecasting process of the Czech National Bank could be enhanced with the use of a satellite model which explicitly takes into consideration financial frictions based on the empirical findings that we propose. Second, such a model could serve as a tool for generating adverse scenarios during stress testing of commercial banks' credit portfolios.

1. Introduction

Research during the past decade indicates that modeling of financial frictions has crystallized into two major branches. One of them stresses the importance of collateral constraints (Iacoviello, 2005), in that fluctuating asset prices affect the availability of bank loans since real estate often serves as collateral against bank loans. The other approach builds on the financial accelerator mechanism, in that credit expansion amplifies economic growth in good times and slows the economy down in bad times due to the existence of linkages between the real economy and the financial markets.

It turns out that the financial accelerator approach, which stems mainly from Bernanke *et al.* (1999), constitutes a channel through which recent events can be explained. This approach was modified numerous times during the past decade – see Dib and Christensen (2008) among many others – and has become a standard toolkit for modeling financial frictions. Brázdik *et al.* (2011) provide a thorough overview of ongoing research in the area, including models in which banks play an active role.

We work with the model of Christiano *et al.* (2011, CTW for short), which was originally developed for the Swedish economy and which makes use of the financial accelerator in explaining business cycle fluctuations.

Previous research carried out at the Czech National Bank supports the idea that financial variables contribute to macroeconomic developments. Brůha (2011) finds that the predictive power of models that include the credit premium is better in terms of real economic activity and the non-performing loan ratio. Havránek *et al.* (2010) propose an empirical analysis based on Czech data and conclude that financial variables have a great impact on the economy, although the influence of financial variables is time-varying so one cannot rely on a single financial indicator when forecasting. Pang and Siklos (2010) use a fully structural model to study the role of the credit spread, which is closely connected to the interest rate spread, in various phases of the business cycle. They highlight the default rate as an important link between banks' credit portfolios and the real economy and suggest that the reaction of the monetary authority should be strong in times of recession as regards policy rate cutting.

Section 2 describes the model structure. Section 3 contains the data description and examines issues regarding the choice of financial variables. The estimation of the model parameters and the calibration to the Czech specifics are discussed in Section 4. In Section 5 we reveal in detail the story of how an adverse financial shock propagates through the entire economy and how the economy gets back to a balanced growth path. In Section 6 we provide a shock decomposition of several model variables. Section 7 demonstrates an experiment of what monetary policy implications are triggered when the model with financial frictions is put to use. Section 8 concludes.

2. Model

CTW (2011) do not start from scratch, but follow what has become the standard New Keynesian model in Smets and Wouters (2003) and Christiano *et al*. (2005, CEE for short) by adding a financial frictions block[1] as in Bernanke *et al.* (1999).

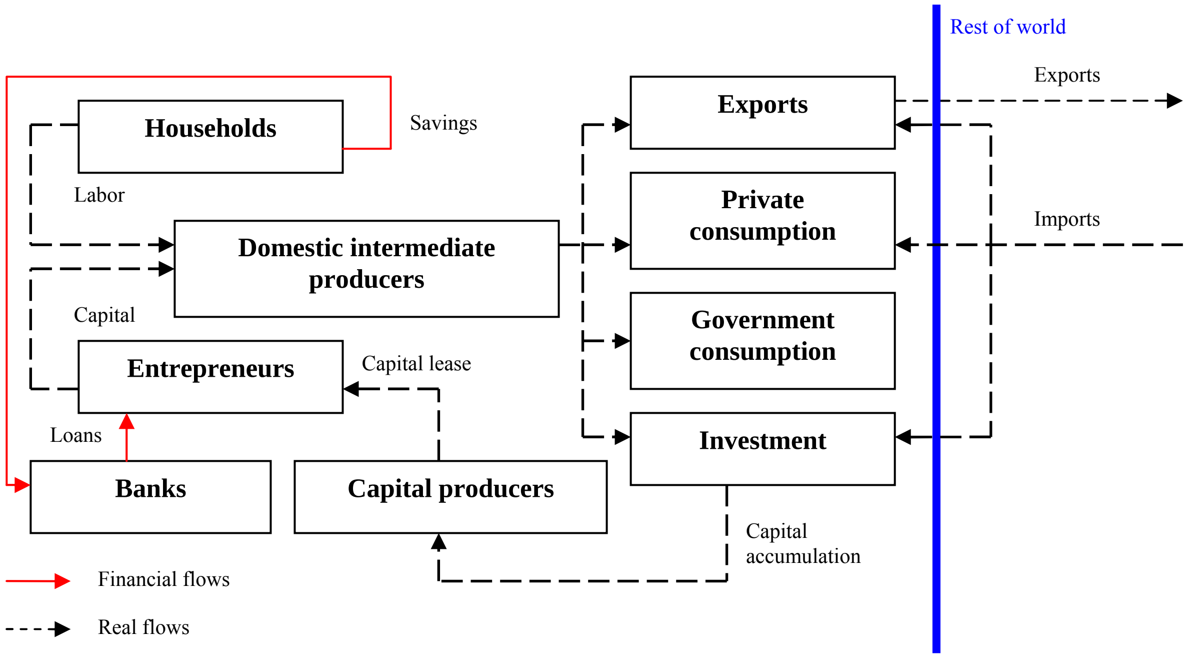
Their model is tailored to handle small open economy issues since it contains an exogenous block of foreign variables, following Adolfson *et al*. (2005) as shown below. The domestic economy is closed by a risk premium according to a modified version of Schmitt-Grohé and Uribe (2003) where households can acquire domestic and foreign assets and the risk premium on domestic assets mixes two effects – the net foreign asset position and the interest rate differential. The former effect has become standard while the latter is motivated by the usual empirical experience, according to which the uncovered interest rate parity assumption in its strict form is counterfactual. A lower domestic interest rate relative to the foreign interest rate may reflect lower country risk and therefore a lower risk premium on domestic assets.

The hump-shaped responses of the core model variables to a monetary policy shock are achieved by incorporating both real and nominal rigidities. In particular, habit formation in consumption of households is introduced, following Fuhrer (2000), while adjustment costs in investment that affect the capital law of motion follow CEE (2005). Nominal rigidities stem from monopolistic competition. Aggregate variables are derived using the Dixit and Stiglitz (1977) production function with constant elasticity of substitution. Price and wage dynamics feature Calvo frictions, as in Erceg *et al*. (2000), where agents who do not get to set the price/wage optimally follow an inflation indexation rule of thumb.

Figure 1 depicts the structure of the model, including the interaction among its main blocks. Here we focus on the production side of the economy and explain how the factors of production are captured by the model. Domestic intermediate producers take labor and capital as inputs into their production function. Households provide labor directly, while there is a chain of agents that contribute to the process of capital transformation, in which financial frictions arise. The initial stock of capital is derived in each period from the past actions. Capital producers then use investment and the functional form for the law of motion of capital to generate the amount of capital available to entrepreneurs. Their capital can be backed either by net worth or by a bank loan and the financial friction enters the model via the riskiness of entrepreneurs' business. The expected return on capital can in fact be less than the amount required to be paid off to the bank, including interest, at the end of each period. Thus, it can happen that a portion of entrepreneurs goes bankrupt. This has economy-wide implications, in that it affects the interest rate setting behavior of banks, by which the interest rate spread is captured. Households deposit their domestic savings in banks and these are then converted into loans.

[1] Their model also incorporates a sophisticated labor market block which endogenizes the unemployment rate.

Figure 1: Model Scheme – Nominal and Real Flows



Further on we describe the financial frictions channel, including a simplified version of the core model equations. The interested reader should look directly into CTW (2011) for a proper definition of all the functional forms.

2.1 Financial Frictions Block

Banks in this model do not have an active role because they only function as intermediaries. Entrepreneurs are risk-taking agents who borrow from a bank and invest in capital. Upon successful investment, they profit from a positive return on capital net of the bank loan and interest. Entrepreneurs also face shocks to their return on capital, which can either increase or reduce the final return on capital. For the entrepreneur there exists a certain threshold value, $\omega = \varpi$, of this shock such that the return on assets times the volume of assets covers the bank loan and the interest, in which case the entrepreneur is left with nothing but has not defaulted, or[2]

$$(1+r)A\,\varpi = (1+i)B, \tag{1}$$

where r is the return on assets, A is the volume of assets, ω is an idiosyncratic shock to the return on assets distributed lognormally with mean centered at one, i is the interest rate, and B is the bank loan. Equation (1) can be rearranged to get ϖ explicitly:

$$\varpi = (1+i)/(1+r)\ B/A.$$

Due to balance sheet constraints, because

[2] We omit the time subscripts of the variables in the case of static equations.

$$A = N + B, \tag{2}$$

the ratio B/A can be complemented with the ratio of net worth to assets (N/A), the inverse of which is usually referred to as the *leverage ratio* in the financial frictions literature. The threshold value of the idiosyncratic shock, ϖ, thus depends inversely on the leverage ratio, which serves as a constraint in the model.

We can combine equations (1) and (2) to get a final equation determining the interest rate spread since

$$i - i_p = \frac{(1+r)\varpi}{1 - N/A} - 1 - i_p, \tag{3}$$

where we subtract the policy rate i_p from both sides of the equation. The left-hand side of equation (3) is mapped linearly on the data in a measurement equation. We describe the exact data counterparts in a separate data section.

The equilibrium loan contract is the one in which entrepreneurs maximize their expected welfare given the threshold value, $E_t\{\varpi_{t+1}\}$, and the time *t* value of leverage (A/N). The associated problem can be written as

$$\frac{E_t\{(1+r_{t+1})A_t\}}{(1+r_t^d)N_t} - bank\ share_{t+1},$$

where the nominal value of assets is taken relative to the guaranteed profit resulting from depositing the net worth in the bank at a deposit rate r_t^d. The total expected profit is net of the amount which goes back to the bank. This bank share is dependent on the expected cut-off value ϖ_{t+1} and problem maximization is subject to the bank's zero profit condition, which is described in the next paragraph. Taking derivatives with respect to ϖ_{t+1} and the leverage yields the first-order conditions, which can be combined together to rule out the Lagrangian multiplier. The optimal contract at time *t* also specifies the *t*+1 contingent rate of interest (*t*+1 actions do not affect the *t*+1 interest rate).

As mentioned above, banks have only a passive role in the model and their expected revenue corresponds with the risk-free rate of return $(1+i_t)B_t$. The entrepreneurs who survived must pay back the loan plus the interest, and those who went bankrupt lose everything. Banks must, however, pay the monitoring cost, μ, in order to reveal the true condition of a defaulted entrepreneur's assets. Since ω is a random variable whose distribution is assumed to be lognormal, we can work easily with its cumulative distribution function. Banks' clearing condition (zero profit condition) equates expected revenue with costs and can be written as

$$(1+i_t)B_t = [\varpi_{t+1} \times prob\{\omega \geq \varpi_{t+1}\} + \omega_{t+1}(1-\mu) \times prob\{\omega < \varpi_{t+1}\}]\,(1+r_{t+1})A_{t+1}, \tag{4}$$

where ϖ_{t+1} is the true expected t+1 threshold value for the idiosyncratic shock that makes entrepreneur break even.[3] This is also an equation entering the model after linearization.

The last model equation from the financial frictions block determines the law of motion for the net worth of entrepreneurs. If an entrepreneur survives and his bank loan is paid off, the excess amount can serve as net worth for the next period. Both survivors and losers receive an initial transfer at the beginning of the next period, which guarantees sufficient funds to obtain a loan. The survival rate, γ_t, is a time-varying parameter modeled as an AR(1) process. The underlying equation for the evolution of net worth, nw_{t+1}, reads as follows:

$$nw_{t+1} = \gamma_t[(1+r_t)A_t\varpi_t - (1+i_t)B_t] + initial\ transfer_t. \tag{5}$$

The small open economy setting is captured in the model via an exogenous foreign block of variables that evolve according to a vector autoregressive scheme:

$$\begin{pmatrix} y_t \\ \pi_t \\ r_t \\ \mu_{z,t} \\ \mu_{\psi,t} \end{pmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ 0 & 0 & 0 & \rho_{\mu_z} & 0 \\ 0 & 0 & 0 & 0 & \rho_{\mu_\psi} \end{bmatrix} \cdot \begin{pmatrix} y_{t-1} \\ \pi_{t-1} \\ r_{t-1} \\ \mu_{z,t-1} \\ \mu_{\psi,t-1} \end{pmatrix} + \begin{bmatrix} \sigma_y & 0 & 0 & c_{14} & c_{15} \\ c_{21} & \sigma_\pi & 0 & c_{24} & c_{25} \\ c_{31} & c_{32} & \sigma_r & c_{34} & c_{35} \\ 0 & 0 & 0 & \sigma_{\mu_z} & 0 \\ 0 & 0 & 0 & 0 & \sigma_{\mu_\psi} \end{bmatrix} \cdot \begin{pmatrix} \varepsilon_{y,t} \\ \varepsilon_{\pi,t} \\ \varepsilon_{r,t} \\ \varepsilon_{\mu_z,t} \\ \varepsilon_{\mu_\psi,t} \end{pmatrix},$$

where the sector-specific technology processes, μ's, are modeled as mutually uncorrelated AR(1) processes that also transmit into the domestic economy. Foreign GDP (y_t), inflation (π_t), and the interest rate (r_t) form a Cholesky block in the VAR.

2.2 Adjusting the Model to Fit the Czech Specifics

Apart from the estimation itself, we have slightly altered the Swedish version of the model in order to closely capture Czech phenomena. The economic situation of Sweden corresponds quite closely to that of the Czech Republic. Both are small open economies that conduct monetary policy in an inflation targeting regime. The exchange rate channel has proven to have strong implications in these countries. This can be deduced from the empirical evidence – see, for example, Babetskaia-Kukharchuk (2007), who estimates the exchange rate pass-through in the Czech Republic at between 25% and 30% (based on a multivariate analysis), or Flodén and Wilander (2004), who estimate the Swedish pass-through at between 19% and 37% (though based on a univariate analysis). The recent credit crisis hit both countries in 2009 via a decline in foreign demand. Measured by real GDP, the economic downturns in the Czech Republic and Sweden amounted to 4.1% and 5.3%, respectively. Finally, both countries appear to be reluctant to adopt the common euro currency in the medium term.

[3] In reality, easing or tightening of the lending conditions is accomplished not only through adjustments in the price of credit, but also through other non-price factors such as credit rationing – we thank Jaromír Beneš for pointing this out.

On the other hand, the CNB used to operate a fixed exchange rate regime until the end of 1997, when this policy stance was abandoned in favor of inflation targeting. The CNB initially targeted the core inflation index, but later switched to targeting of the consumer price index. Moreover, over time, the inflation target levels have dropped from around 6% in 1998 to the current 2% valid as of 2010.

To tie the model prices to this disinflation period in Czech history, we constructed an extra measurement equation that links the model target values to those observed in the data:

$$target_t^{data} = target_t^{model} + \Omega_t. \tag{6}$$

We keep the measurement error, Ω_t, in this equation at zero since we do not allow the model structure to deviate from the prescribed target values in history. The target itself is then modeled as an AR(1) process

$$target_t^{model} = \rho\, target_{t-1}^{model} + \varepsilon_t,$$

where the shock, ε_t, has non-zero variance so that the model value of the target can always be glued to the data via the measurement equation (6). The time t expected deviation of inflation from the inflation target at t+4 then enters the standard Taylor-type rule, according to which the interest rate is set by the monetary authority.

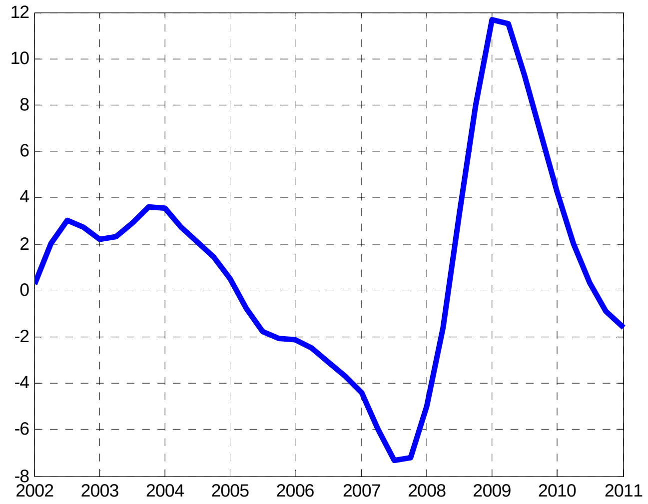
3. Data

To capture financial frictions in real data, we need to introduce two observable variables concerning financial frictions – a measure of the interest rate spread and a measure of entrepreneurial net worth. We closely follow the choice of CTW (2011), even though it is not clear at all whether this selection of financial variables is the correct one, as will be discussed below.

3.1. Interest Rate Spread

We calculate the interest rate spread as follows. The dip in the PRIBOR during the 2009 crisis was not immediately followed by a general decrease of market interest rates. Therefore, we take the average interest rate on newly issued credit to non-financial corporate obligors and subtract the 3-month PRIBOR. The idea behind this choice is that rates for non-financial corporations serve both as a representative market interest rate and as one that is close enough to entrepreneurial borrowing in the model of CTW (2011). On the other hand, the 3-month PRIBOR, being strongly correlated with the regulated 2-week PRIBOR, is believed to track monetary policy actions closely. We do not take the policy rate itself in constructing the interest rate spread because of the maturity mismatch in comparison to the representative market rate. Figure 2 shows the quarter-to-quarter percentage changes in the interest rate spread. The obvious upward shift in 2009 coincides with the increased risk during the post financial turmoil period.

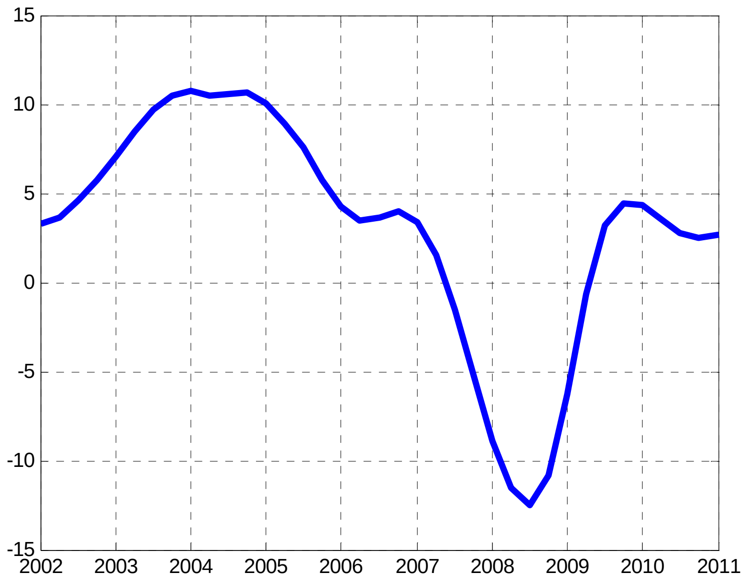
Figure 2: Interest Rate Spread, % Changes, HP(10)



3.2 Entrepreneurial Net Worth

We take the approach of CTW (2011) and approximate the entrepreneurial net worth in the model with the aggregate stock market index even though this choice has its drawbacks. Figure 3 shows the quarter-to-quarter percentage changes in the Czech PX index. The double digit falls precede the moment when, in the first quarter of 2009, the real economy was hit hardest by the global crisis.

Figure 3: PX Stock Market Index, % Changes, HP(10)



While it is quite intuitive to find a reasonable data counterpart for the interest rate spread, our choice concerning entrepreneurial net worth is somewhat trickier. In the discussion that follows, let us suppose that stock prices are determined to a great extent by dividend payments. This is in line with Dhillon and Johnson (1994), who examine the impact of dividend changes on the stock and bond markets and provide evidence which does not contradict the information content hypothesis of dividend payments, i.e., that stock prices should increase (decrease) when dividend increases (decreases) are announced. Miller and Modigliani (1961, MM for short) suggest dividend neutrality in their seminal paper on the information content hypothesis of dividends. On the other hand they assume that changes in dividend policy form a signal about the state of a company.

In the literature, one can find counterarguments to this theory, often based on the fact that MM (1961) assume perfect capital mobility, perfect information, and zero transaction costs, as argued in Baker (1992). The dividend yield is also subject to higher taxation than the regular capital gain. Growth in dividends can then represent negative information and can cause drops in stock prices.

It is a well-known fact that dividend payments develop very smoothly over time, as claimed by Lintner (1956) and Brav *et al.* (2003). Stable dividend policy is perceived positively by investors and companies try hard to accomplish this. Therefore, it is up to the management to decide what signals about their company to release, regardless of the true shape of the company. The stronger the correlation between dividend policy and stock prices, the weaker the information content of stock prices regarding the true shape of companies. There are two well-documented examples in U.S. history worth mentioning that depict significant distortions between stock price signals and the real condition of companies.

First, there is an example which dates back to 1919 and which later became known as the Dodge versus Ford case, filed at the Supreme Court of Michigan.[4] This case resulted in the verdict that shareholders' right to claim for a regular (i.e., stable) dividend is justifiable.[5]

Second, during the Great Depression in the USA, firms were even willing to sell their physical capital in order to keep their dividend payments high, as CTW (2011) emphasize. Thus, the real net worth of companies did not correspond to share prices since, from the viewpoint of the preceding discussion, there was bias between what was going on in companies on the one hand and what information the stock prices provided on the other. Of course, fiddling with dividend payments did not prevent a downswing of stock prices after all.

Regardless of the uncertainty concerning the information content of the stock market index, this measure is very sensitive to general public opinion and is quite often used as a leading indicator, although the stock market in the Czech Republic is still relatively shallow – instead, it would be

[4] A scholar's version of the verdict is available at http://www.businessentitiesonline.com/professors.html under Dodge v. Ford Motor Company.

[5] In particular, Henry Ford, president of Ford Motor Company, intended to retain most of the profits in order to reinvest them in the future. His motivation for putting a large share of profits back into the business was that the company would

> *"employ more men, to spread the benefits of this industrial system to the greatest possible number, to help them build up their lives and their homes."*

As a result, he planned to cut the dividend amounts, something that was not welcomed by the Dodge brothers, then major shareholders of Ford Motor Company. The Supreme Court affirmed that the release of dividend payments was not entirely at the discretion of the company's management, but was rather an obligation.

possible to make use of micro-level corporate accounting data, which is left for future investigation.

Finally, we also considered the case where entrepreneurial net worth is not linked to the data at all, and instead we focused on mapping the model default rates on aggregate credit data collected from commercial banks (available for public use in the CNB's ARAD database[6]). However, the default rate data for public use are available only since 2002, which would reduce our sample size by almost a half. We could partially get around the short sample range if we used the "missing data Kalman filter" routine as in Harvey (1989), which we do not attempt.

4. Estimation

Our data sample includes 61 observations covering the period 1996Q2–2011Q2. The data for 1996Q1 are also known but drop out of the sample when first differences are taken. Besides the already discussed interest rate spread and stock market index, which approximate our financial variables, we use a standard set of macro variables which includes the expenditure side of the national accounts in real denomination and the appropriate deflators, the real exchange rate, nominal interest rates for both the domestic economy and the eurozone, foreign GDP and prices, the real wage, the unemployment rate, and hours worked. See CTW (2011) for a precise list of the data transformations used.

4.1 Computational Aspects

To reveal the effects of financial frictions specific to the Czech economy, we process the model through a Bayesian estimation routine in Dynare[7], which is suitable software capable of handling rational expectations models.

First, the posterior modes and the approximation of the Hessian evaluated in these modes are computed using numerical optimization techniques – nonlinear simplex combined with Newton gradient steps. Second, posterior sampling of the parameters is achieved with the help of the Metropolis-Hastings (MH) algorithm with a random walk transition rule.

We set the MH algorithm to generate 500,000 draws, of which 1/3 are discarded as a burn-in. In total we run two parallel MH blocks. The acceptance ratio of the MH draws fluctuates around 35%. Appendix C shows the convergence statistics.

4.2 Parameter Setting

Table B1 in Appendix B shows a comparison of the Czech and Swedish model calibrations of the parameters that are not estimated. The basic setup of the prior assumptions concerning the relevant model parameters and respective posterior estimates is summarized in table B2 and subsequent output figures from Dynare.

[6] http://www.cnb.cz/en/statistics/index.html

[7] Available at www.dynare.org. Koop (2005) derives the underlying mathematical formulas.

The calibrated parameters include the steady state values, deep parameters, and specifications for several persistence coefficients of shock processes. Our calibration closely follows CTW (2011) with several exceptions that we discuss below. According to the Czech national accounts the long-run ratio of investment to GDP is higher than the one suggested by CTW (2011), so we increased the steady state of this ratio from 17% (the Swedish case) to 27%. We altered the rest of the great ratios in a similar way. According to our experience, significant shares of investment and exports are imported into the Czech Republic, which is why we set higher import intensities compared to Sweden – 70% for investment and 62% for exports. The value of the investment import share could be even higher due to foreign direct investment, which had a great impact on our economy in past years. On the other hand, setting this value higher than 70% results in an ill-defined steady state for some of the other model variables. The steady state cut-off value that splits defaulted entrepreneurs from non-defaulted ones is set to 0.4916, which guarantees a default rate equal to 1%. Again, evidence from aggregate corporate loan data would suggest a higher equilibrium default rate, which would cause an ill-defined steady state for other variables. We keep the persistence coefficients of mark-up shocks turned off, as in CTW (2011), with the exception of imported export goods producers and domestic intermediate output producers. The non-zero persistence in these sectors allows for better model behavior on the history, in that the filtered scaled net foreign assets (NFA) variable does not contain a trend. The necessity of doing so emanates from a higher weight of NFA on the risk premium (15%) compared to Sweden (1%). Capital depreciation, being one of the core model parameters, is preset to 0.015 and further computed in a separate steady state file, as are most of the rest of the steady state values (which is why "N/A" values are given in Table B1 for parameter δ). We calibrate the q-o-q composite technology growth to 0.63% (as against 0.42% in Sweden), which reflects the long-run growth of real domestic output.

The prior judgments regarding the parameters that we estimate using Bayesian methods are mostly adopted from CTW (2011). Alternatively, we consider parameter setting according to our previous experience. Unlike in the original Swedish estimation, the parameter measuring banks' monitoring costs, μ, has its posterior mean equal to only 0.37 (i.e., in order to monitor clients in default, banks lose roughly 1/3 of the amount that they would otherwise receive in the absence of monitoring costs), which suggests that Czech banks do not face severe costly state verification as in the Swedish case (0.56). Concerning the foreign VAR block, our results often referred to parameter $a11$ being greater than 1, which would imply unstable foreign GDP. To overcome this difficulty, we set an extra constraint in Dynare making the $a11$ parameter smaller than 1 in absolute value. In this case the posterior estimate came out at 0.91. Our prior belief that the response of interest rates to the output gap is not significant compared to the response to inflation seems to be true because the ratio of these prior weights went down from 0.12/1.7 (≈ 0.07) to 0.09/1.68 (≈ 0.05). This of course amplifies the response of interest rates to inflation, which is not surprising for a country in an inflation targeting regime.

5. Response of Economy to Adverse Financial Shock

The essence of financial frictions can be clearly seen if we consider a shock that reduces entrepreneurs' net worth and trace its propagation to other relevant variables.[8]

5.1 Link between Leverage and Bankruptcy Rates

In a simplified balance sheet of an individual entrepreneur, there are assets backed by net worth and a bank loan. If the entrepreneur is to pay off the bank loan plus the interest by the end of current period, then the return on assets must be sufficiently high to cover the liabilities payable to the bank, including interest. With respect to an agent-specific shock to the return on assets,[9] the profitability of the investment project can be significantly affected. The entrepreneur declares bankruptcy if the adverse shock reaches a certain threshold value at which the return on assets just covers the bank loan plus interest. Such threshold value is thus a function of the volume of assets and the amount of the bank loan, or the ratio of the two.

If the assets are backed mostly by a bank loan, then the interest costs trim down the profit tremendously and the entrepreneur is more vulnerable to adverse shocks. Likewise, should the assets be covered mainly by net worth, the interest costs from the bank loan would not affect the profits very much and the entrepreneur would therefore be relatively immune to adverse shocks. Through this channel we introduce a balance sheet constraint into the model.

The ratio of assets to the amount of the bank loan can be complemented with the ratio of assets to net worth (leverage). *Ceteris paribus*, an adverse shock to net worth implies that a constant volume of assets is backed by a higher bank loan amount and the leverage ratio increases.[10] Consequently, even a slight adverse shock to the return on assets makes the entrepreneur more likely to go bankrupt, which increases the default rate of all entrepreneurs from the aggregate viewpoint.

5.2 Shock Propagation

Appendix A (Figure A1) contains the economy's response to an adverse shock to entrepreneurial net worth. The shock is accompanied by a higher default rate (see the explanation in the preceding subsection), which pushes down overall investment activity since increasing numbers of entrepreneurs go bankrupt. Imports also shrink owing to the import intensity of investment. This causes a reaction on the forex market and the domestic currency appreciates on account of the trade surplus, which decreases the inflationary pressures due to lower import prices. In this situation the monetary authority lowers the policy rate, which in normal circumstances should lead to a general decline in market rates. But instead, financial frictions suppress this decline

[8] The analysis of impulse-response functions is based on a first-order approximation of the model.

[9] Heterogeneity of agents is emphasized by the fact that each entrepreneur faces his or her specific shock to return on assets. The model then works with the distribution of all entrepreneurs.

[10] The final balance sheet effect of the lowered net worth is questionable. On the one hand, net worth could be offset by a larger bank loan to keep the volume of assets constant, or, on the other hand, the lowered net worth could result in a reduction in both assets and liabilities. The model we work with assumes the first approach, but equilibrium is restored with help of the latter approach as discussed later.

because commercial banks face higher provisions due to write-offs and keep interest rates high to offset the worse credit risk conditions. Thus, monetary policy efforts are dampened by an elevated interest rate spread.

In what usually follows in reality, banks are forced to ease the credit conditions because, first, they face competition, and second, the spread closes after several quarters. This gradually pulls up investment activity and the economy recovers.

Specifically, the model contains a built-in stabilizer that helps to explain why the economy returns to a steady state after experiencing an adverse shock to entrepreneurial wealth. When the economy slows on account of weak investment, asset prices freeze and this has two consequences. First, investment activity is automatically stimulated since it becomes cheaper. Second, given the entrepreneurial balance sheet constraint, the volume of nominal assets shrinks, which pushes down the leverage ratio and investment activity is stimulated again. These two effects together outweigh the higher default rate and the economy eventually reaches a stationary state. Finally, defaulted entrepreneurs are given an initial amount of net worth every period, which also helps the economy to reach a stationary state (see the initial transfer in equation 5).

6. Shock Decomposition

In a class of linearized models, it is possible to identify fluctuations of endogenous variables resulting from shocks that hit the model in each period. In the absence of shocks, the model variables would stick to their steady state values. To uncover whether financial frictions help to explain a substantial portion of the business cycle in the Czech Republic, we construct *ex post* decomposition graphs for relevant model variables (see Appendix D – the shaded grey area in the graphs marks the beginning of the economic downturn due to the financial crisis).

The output gap is positive in the period 2006–2007, mainly due to technological shocks, mark-up shocks, and increasing habit shocks in consumption. The sharp downturn in output in 1Q2009 is mainly caused by negative financial shocks. The real investment gap is explained to a great extent by financial shocks. This is a result of how investment decisions are modeled – a separate agent called an entrepreneur, who is bound by financial conditions from his balance sheet, decides on the utilization of capital. The real import gap is also affected by financial shocks due to the high share of imports in investment. The interest spread and net worth are financial variables themselves, therefore a major part of the fluctuations in these variables results from financial shocks. This is partially offset by marginal investment efficiency shocks in the opposite direction in the case of the interest rate spread.

On the other hand, foreign demand shocks and domestic mark-up shocks dominate in explaining real export fluctuations. Private consumption features very persistent preference shocks. Positive technology shocks contributed to lower inflation and lower interest rates in the period 2003–2007. Government consumption is exogenous in the model, so only fiscal shocks take effect.

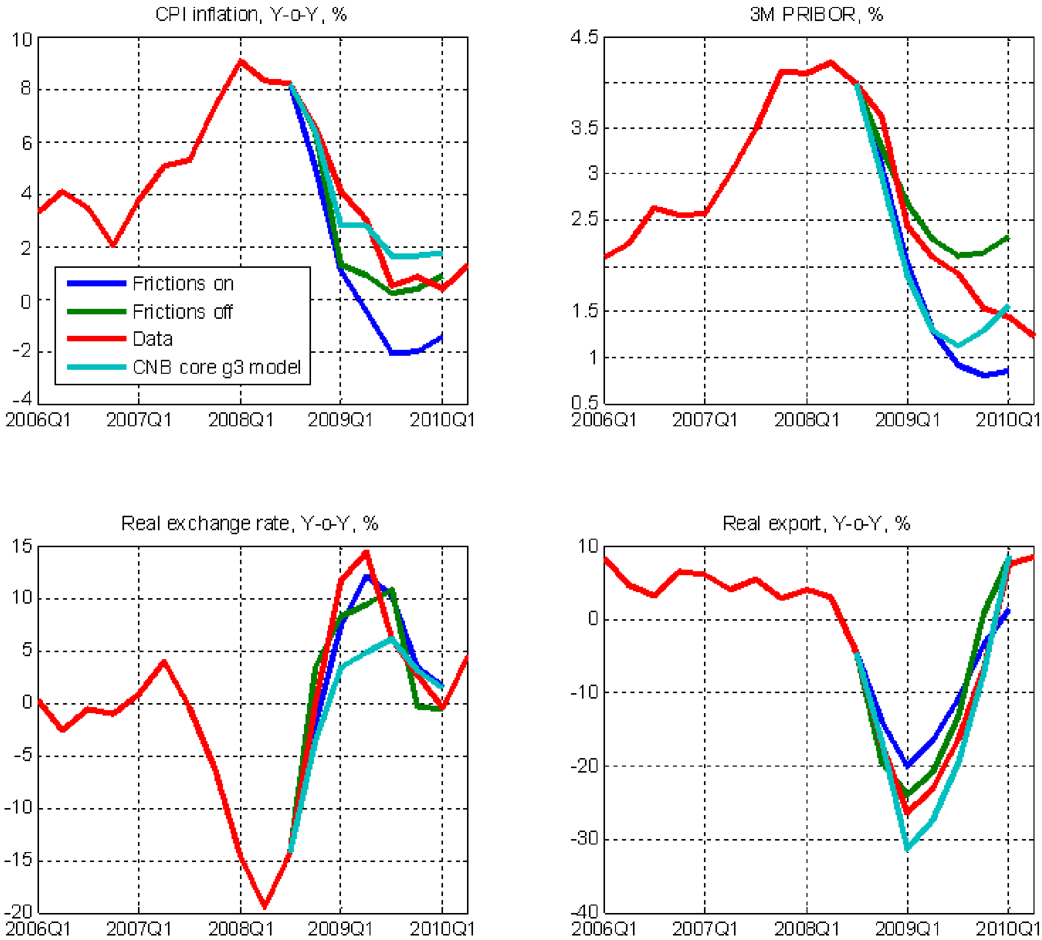
7. Monetary Policy Implications

To demonstrate the impact of financial frictions on the model dynamics, we carried out forecast exercises[11] conditional on the current knowledge of the model's exogenous variables. We take known data up to 2008Q3 and replicate the forecasts in turn for the model with financial frictions as discussed above, the model in which financial frictions are turned off, and finally a forecast of the CNB's core g3 model, which does not feature financial frictions explicitly. In the end we compare all the forecasts with the actual development of the relevant variables. Figure 4 shows the predictions for the CPI, the interest rate, the real exchange rate, and real exports. The simulations begin in 2008Q3 and run six quarters ahead. In this set of scenarios, the outlook for foreign exogenous variables is taken according to the known reality and the forecast simulation is calculated forward as if the model agents did not anticipate the development of the foreign outlook[12] in advance. On the contrary, the 2% inflation target holds over entire forecast range and is fully anticipated. We do not make any other expert judgments, leaving both predictions genuinely model implied and thus comparable.

[11] By forecast we do not mean the CNB's official forecast at the time, we mean mechanical model simulations conditional only on currently known information on the exogenous variables and specified model structures.

[12] The rational expectations modeling approach allows us to generate a forecast based on the future expected paths of the relevant variables, which we do not attempt here.

Figure 4: Conditional Prediction (Model Comparison)



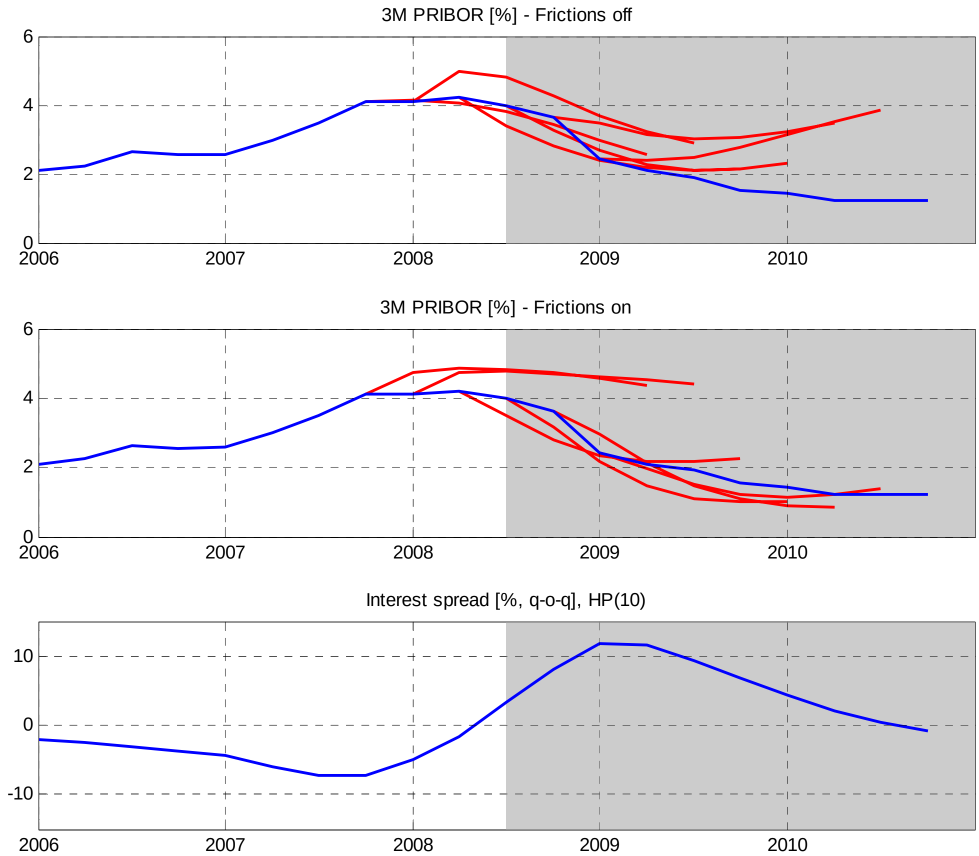
Considering the size of the economic slump in 2009, the simulated interest rate paths of all the models closely trace the realized paths given the outlook for foreign exogenous variables. However, the model with financial frictions suggests a more significant interest rate cut compared to the model in which the financial frictions block is neglected. The effect of financial frictions, which mostly results from the elevated interest rate spread, increases over time – the difference between the models with and without frictions is more than 100 basis points at the end of the forecast horizon. This outcome is in line with Tonner and Vašíček (2011), who estimate the effect of financial frictions at around 50 basis points. However, to draw proper conclusions, one should not interpret Figure 4 in favor of the model with financial frictions turned off just because the implied prediction fits the realized trajectory of the interest rate better. Expert judgments, which we do not impose at all, form a significant part of the whole forecasting process. Thus, Figure 4 only suggests that the interest rate cutting process with respect to the financial frictions channel would be firmer and longer lasting than in the case of no financial frictions.

From the technical point of view, financial frictions are switched off in the model as follows. The parameter of monitoring costs of banks is fixed at zero, which results in banks knowing the current status of the obligor's property with certainty without the need for further costly inspection. Furthermore, the persistence of the net worth of entrepreneurs is kept at zero, allowing greater flexibility of entrepreneurial borrowing because shocks to net worth no longer propagate to the future and the net worth of entrepreneurs is thus more likely to wander more closely around its steady state value. On the other hand, we still have the entrepreneur as an agent who makes decisions about capital utilization.[13]

The judgment-free prediction of the interest rate in the case of the CNB's core g3 model (which does not contain an explicit financial frictions mechanism) more or less coincides with the CTW model with frictions turned on. Only at the end of the forecast horizon does the interest rate revert back to the steady state more rapidly.

During the pre-crisis period the CTW models with and without financial frictions suggest a similar interest rate trajectory. Figure 5 illustrates the gradual dispersion between the two forecast scenarios as the interest rate spread began to rise. This exercise was calculated as a recursive forecast. Since early 2009 the CTW model with financial frictions captures the reality with substantially greater success.

Figure 5: Recursive Forecast Exercise – Shaded Area Marks Period of Rising Interest Spread



[13] The proper way to turn off financial frictions would involve capital decisions being made by households.

8. Conclusion

As the recent global crisis fades away, we try to evaluate the relevance of macro-financial linkages in the case of the Czech Republic. We focus on the interest rate spread as a key factor that makes monetary authority actions ineffective at times of adverse risk conditions.

We work with the Swedish model of CTW (2011), which incorporates several mechanisms with various frictions in a small open economy setting. We concentrate on the channel of financial frictions based on the financial accelerator literature in the light of Bernanke *et al*. (1999). The core model parameters are calibrated with respect to the Czech specifics, and the rest of the parameters are estimated using Bayesian techniques. The original model structure of CTW is slightly altered in order to capture the differences between Sweden and the Czech Republic. For example, we introduce a disinflation scheme as an observed variable and link this data to the model inflation target.

To explore the influence of financial frictions, we conduct a pair of experiments to reveal the extent of macro-financial linkages in the Czech Republic.

First, we run pre-crisis judgment-free forecasts with the CTW model with financial frictions turned on and off and compare them with the actual development of the interest rate and the forecast implied by the g3 model. The results suggest that the monetary authority should react faster with policy rate cutting when financial frictions are taken into consideration.

Second, we investigate whether the effects of financial frictions are time dependent. On a series of recursive forecasts we demonstrate that the effect of financial frictions seems to be limited at times when the interest rate spread is relatively low, since the CTW models with and without frictions show similar behavior. The difference in the forecasting powers between these two models becomes significant as the interest rate spread increases.

According to the Czech experience, the exchange rate channel connected with the balance of net exports is believed to be the main driver of the business cycle. These properties are implemented into the g3 model carefully and make its forecast performance comparable to the CTW model even though no financial sector is assumed in the g3 model. The inclusion of financial frictions does not contradict the relevance of other channels in that the effects of financial frictions do not tend to dominate during various business cycle phases. Perhaps the Czech economy is “too open” to be affected by a mechanism that propagates through real investment.

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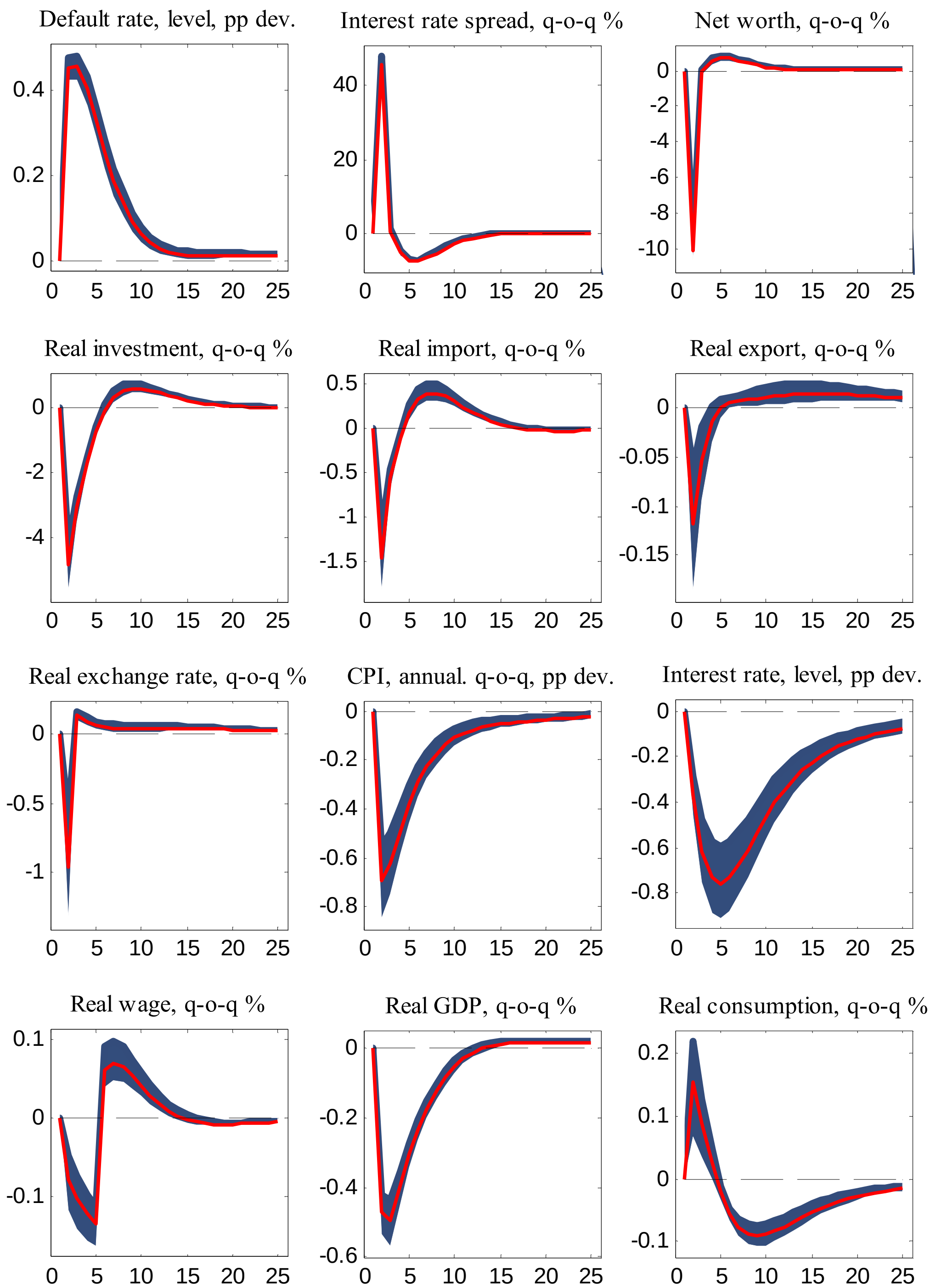
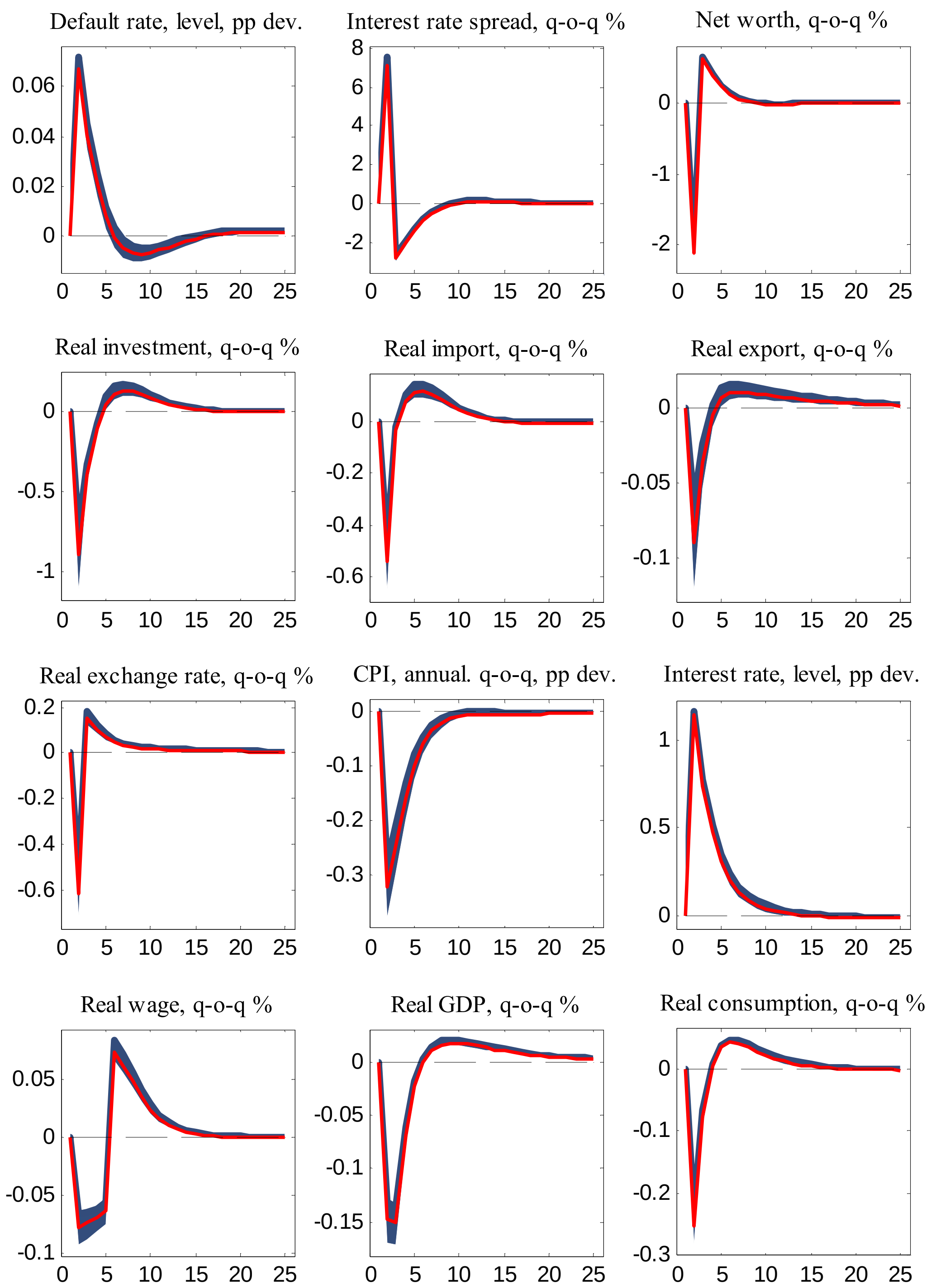
Appendix A : Impulse Response Functions

Figure A1: Adverse Financial Shock (negative 1 std entrepreneur wealth shock)



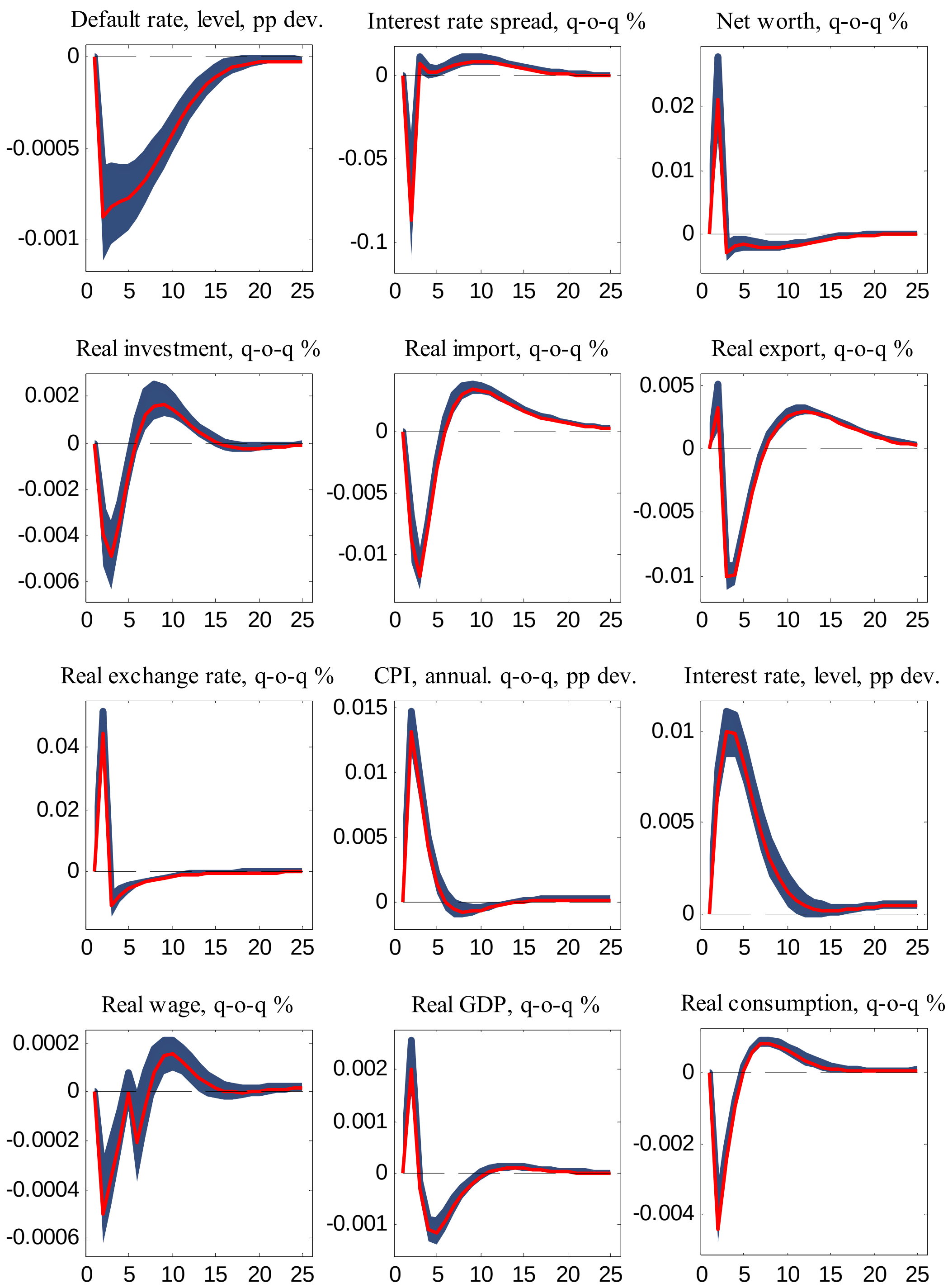
Note: posterior mean (red), 90% confidence bands (dark). Units on vertical axis are measured as quarter on quarter growth rates (q-o-q %), or percentage point deviations from steady state (pp dev.) – dashed line = steady state.

Figure A2: Monetary Policy Shock (positive 1 std shock)



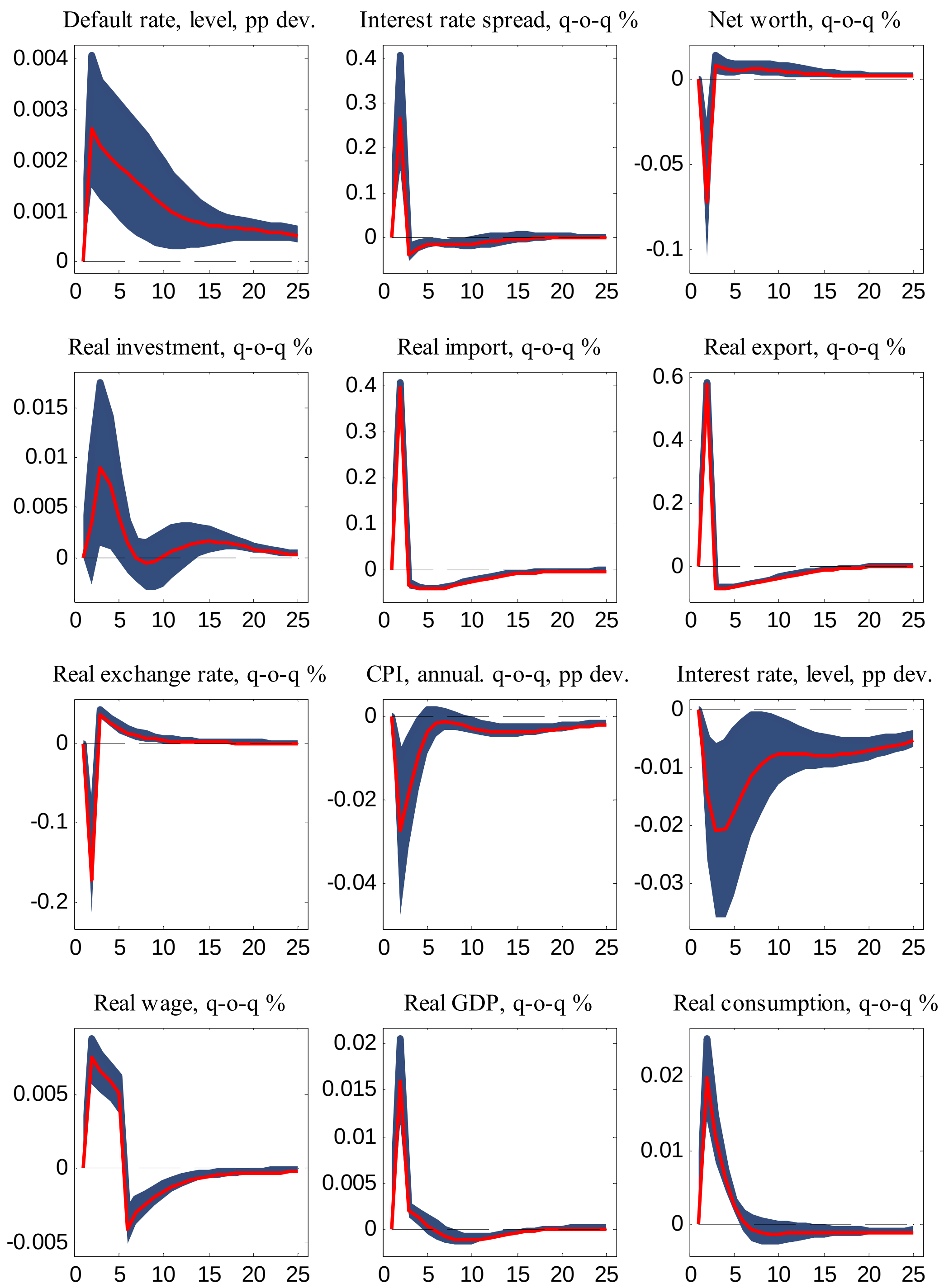
Note: See Figure A1.

Figure A3: Foreign Interest Rate Shock (positive 1 std shock)



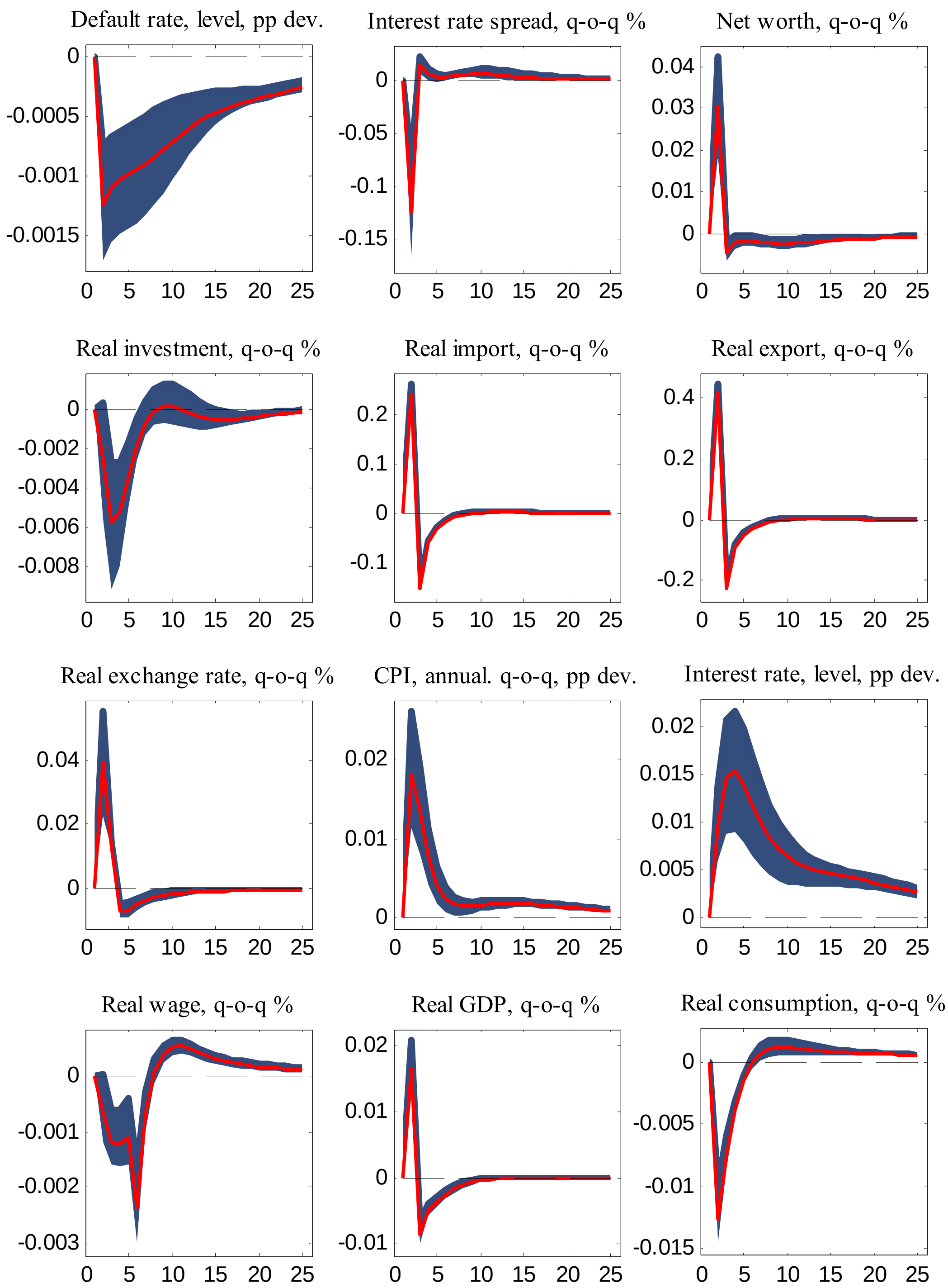
Note: See Figure A1.

Figure A4: Foreign Demand Shock (positive 1 std shock)



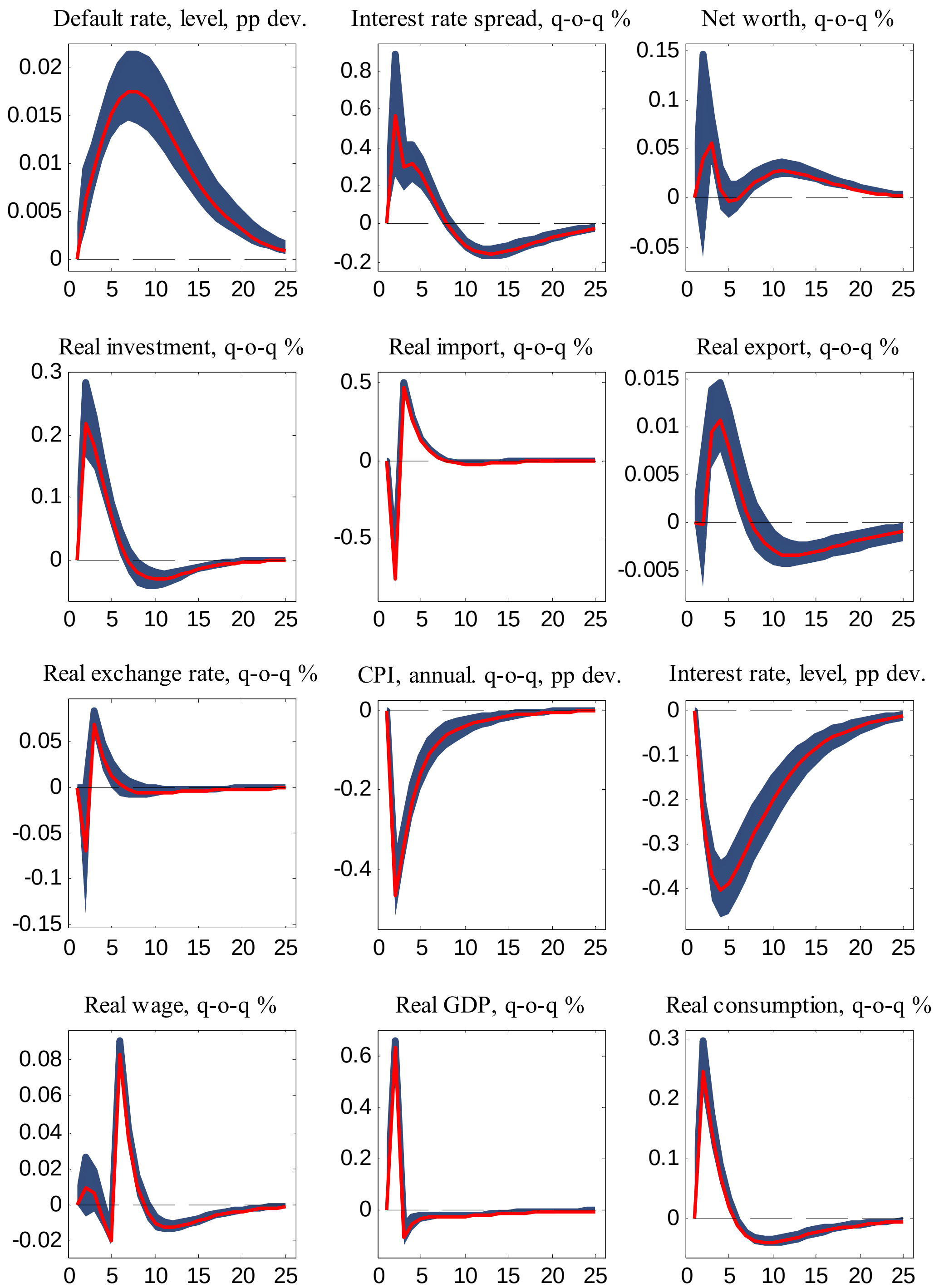
Note: See Figure A1.

Figure A5: Foreign Inflation Shock (positive 1 std shock)



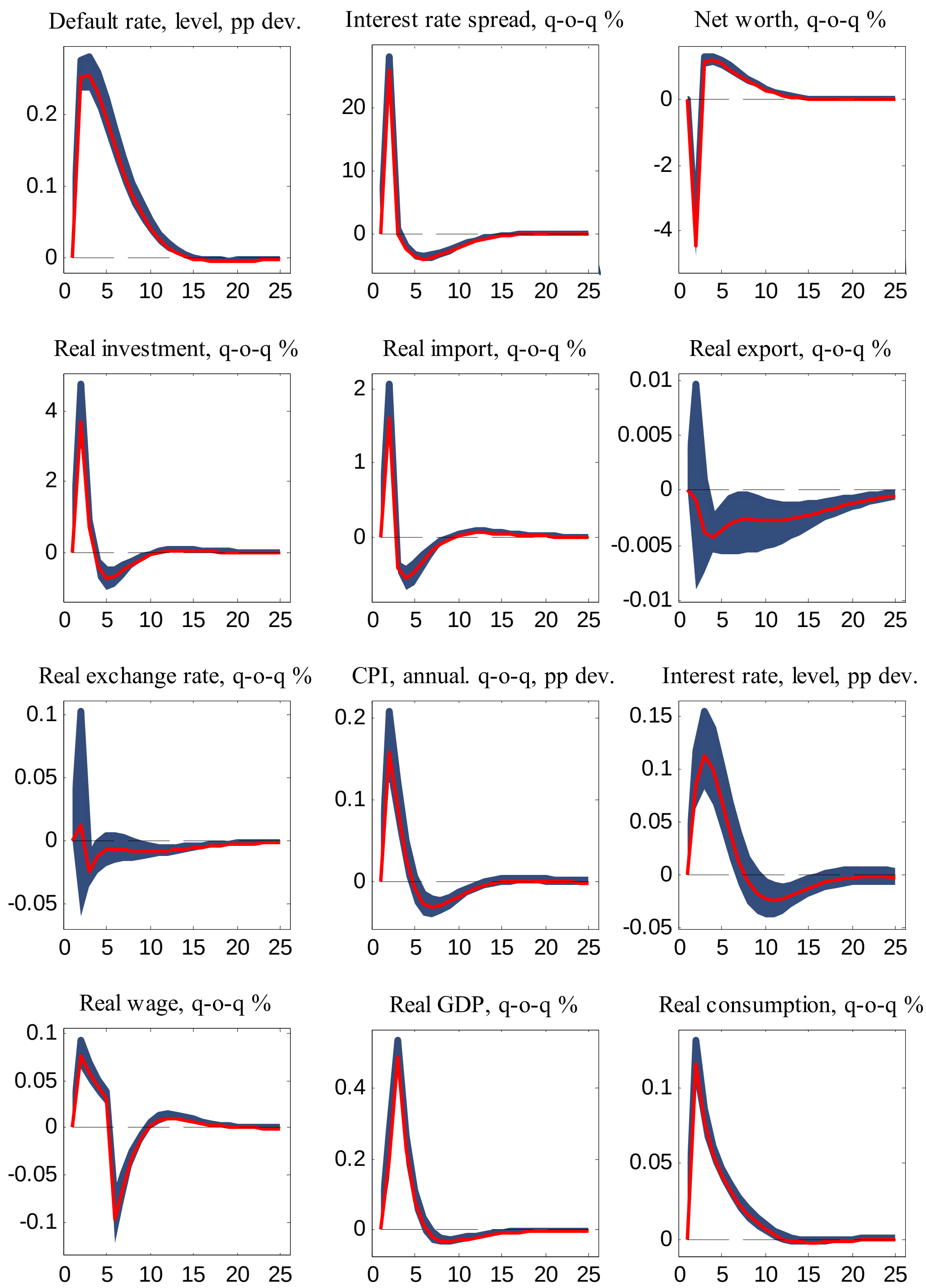
Note: See Figure A1.

Figure A6: Neutral Technology Shock (positive 1 std shock)



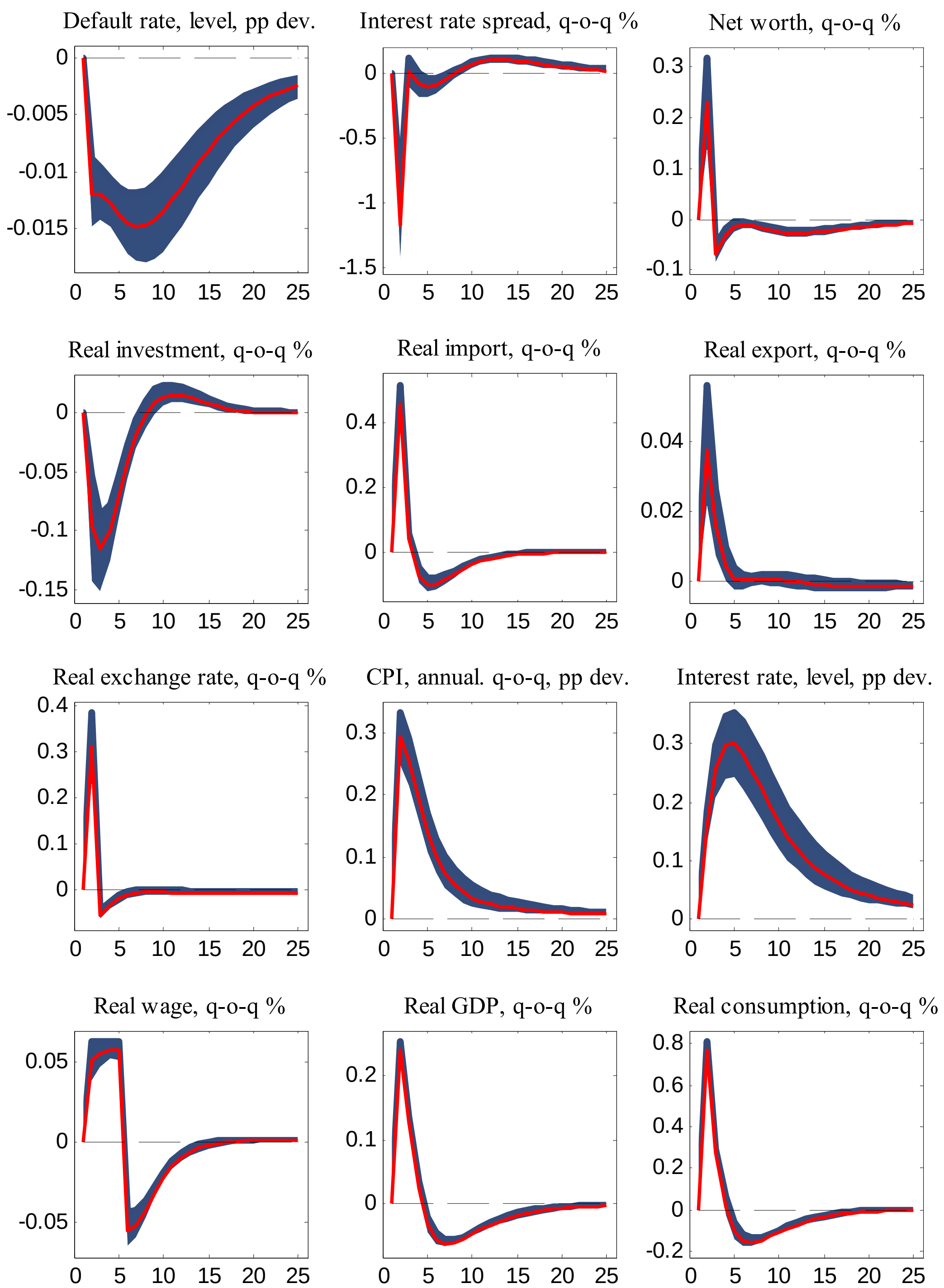
Note: See Figure A1.

Figure A7: Marginal Efficiency of Investment Shock (positive 1 std shock)



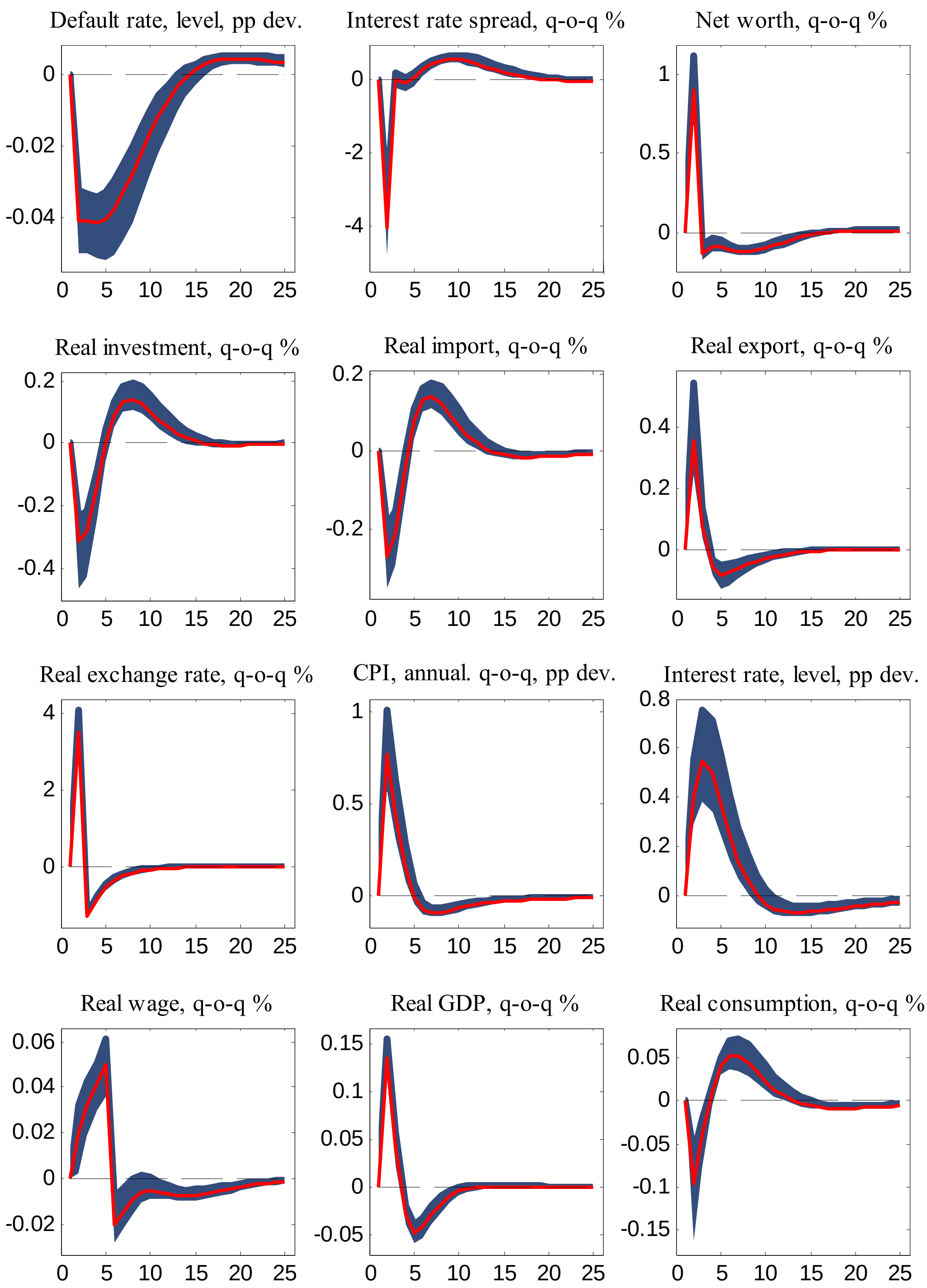
Note: See Figure A1.

Figure A8: Consumption Preference Shock (positive 1 std shock)



Note: See Figure A1.

Figure A9: NFA Risk Shock (positive 1 std shock)



Note: See Figure A1.

Appendix B: Model Parameters

Table B1: List of Calibrated Parameters

Parameter	Interpretation	Czech Republic	Sweden
	Great ratios		
i^y	SS weight of investment on GDP	0.27	0.17
g^y	SS weight of government consumption on GDP	0.24	0.30
x^y	SS weight of exports on GDP	0.45	0.45
	Import shares		
Ω^c	import intensity of consumption	0.25	0.25
Ω^i	import intensity of investment	0.70	0.43
Ω^x	import intensity of exports	0.62	0.35
	Financial frictions		
nw^{ini}	initial value of net worth given to entrepreneurs	0.01	0.01
ω	SS cut-off value for defaulted entrepreneurs	0.4916	0.4916
	Persistences of AR(1) processes		
$\rho^{\tau}{}_{x}$	mark-up shock in export pricing	0	0
$\rho^{\tau}{}_{mc}$	mark-up shock in imported consumption	0	0
$\rho^{\tau}{}_{mi}$	mark-up shock in imported investment	0	0
$\rho^{\tau}{}_{mx}$	mark-up shock in imported export	0.25	0
$\rho^{\tau}{}_{d}$	mark-up shock in domestic homogeneous good	0.3	0
$\rho^{\tau}{}_{y}$	fiscal shock	0.85	0.85
$\rho^{\tau}{}_{z}$	investment specific technology	0.5	0.5
$\rho^{\tau}{}_{\sigma}$	shock to return on capital	0.85	0.85

Table B1: List of Calibrated Parameters - Continued

Parameter	Interpretation	Czech Republic	Sweden
	Other		
δ	capital depreciation	N/A	N/A
u	SS unemployment rate	0.08	0.08
α	capital share in production	0.375	0.375
β	discount rate	0.9986	0.9986
μ_{z+}	q-o-q composite technology growth	0.63%	0.42%
π^{target}	annualized inflation target	2%	2%
π^{*}	annualized SS*) of foreign price growth	2%	2%
ϕ^{a}	weight of NFA on risk premium	0.15	0.01

Note: *) SS = steady state

Table B2: List of Priors and Posteriors

Parameter	Interpretation	Distr.	Prior		Posterior		
			mean	**std**	**mean**	**5%**	**95%**
	Calvo parameters						
ξ_d	domestic intermediate good producer	β	0.87	0.075	0.89	0.879	0.898
ξ_x	export good producer	β	0.78	0.075	0.69	0.678	0.721
ξ_{mc}	consumption importer	β	0.85	0.075	0.67	0.650	0.700
ξ_{mi}	investment importer	β	0.78	0.075	0.58	0.558	0.606
ξ_{mx}	export importer	β	0.65	0.10	0.51	0.466	0.568
	Price indexation on lagged inflation						
κ^d	domestic good producer	β	0.15	0.05	0.13	0.121	0.161
κ^x	export producer	β	0.49	0.15	0.36	0.286	0.462
κ^{mc}	imports for cons. producer	β	0.29	0.15	0.21	0.129	0.299
κ^{mi}	imports for investment producer	β	0.61	0.15	0.30	0.245	0.361
κ^{mx}	imports for export producer	β	0.38	0.15	0.32	0.244	0.419
κ^w	wage indexation	β	0.38	0.15	0.02	0.008	0.036
	Taylor rule						
ρ^R	interest rate persistence	β	0.82	0.10	0.83	0.805	0.849
r^π	weight of deviation of inflation from target	truncated N	1.70	0.15	1.68	1.535	1.774
r^y	weight of output gap	truncated N	0.12	0.05	0.09	0.074	0.124
	Persistences of AR(1) processes						
ρ^{μ_z}	composite technology growth	β	0.86	0.10	0.93	0.882	0.970
ρ^ε	neutral technology growth	β	0.85	0.075	0.87	0.855	0.895
ρ^Υ	shock to marginal efficiency of investment	β	0.55	0.075	0.59	0.531	0.645
ρ^{ζ_c}	consumption preference shock	β	0.72	0.075	0.78	0.737	0.823
ρ^{ζ_h}	labor preference shock	β	0.80	0.075	0.86	0.822	0.925
$\rho^{\tilde{\phi}}$	risk premium shock	β	0.67	0.075	0.59	0.517	0.672

Table B2: List of Priors and Posteriors - continued

Parameter	Interpretation	Distr.	Prior mean	Prior std	Posterior mean	Posterior 5%	Posterior 95%
ρ^g	government shock	β	0.80	0.075	0.77	0.691	0.824
ρ^γ	shock to net worth I	β	0.78	0.075	0.62	0.579	0.679
ρ^σ	shock to net worth II	β	0.85	0.075	0.95	0.947	0.970
	Elasticities of substitution						
η^x	exports	truncated Γ	1.31	0.25	1.04	1.007	1.099
η^c	consumption	truncated Γ	1.63	0.25	1.96	1.870	2.067
η^i	investment	truncated Γ	1.53	0.25	1.58	1.313	1.848
η^f	foreign demand for exports	truncated Γ	1.55	0.25	1.99	1.923	2.060
	Foreign VAR						
$a11$	gdp persistence (Y*)	truncated N	0.50	0.25	0.91	0.844	0.959
$a22$	inflation (Π*) persistence	N	0.00	0.50	0.09	-0.120	0.272
$a33$	interest rate (R*) persistence	truncated N	0.50	0.25	0.88	0.806	0.955
$a12$	$\Pi^*\rightarrow Y^*$	N	0.00	0.50	0.20	0.003	0.403
$a13$	$R^*\rightarrow Y^*$	N	0.00	0.50	0.06	-0.124	0.231
$a21$	$Y^*\rightarrow \Pi^*$	N	0.00	0.50	0.18	0.088	0.271
$a23$	$R^*\rightarrow \Pi^*$	N	0.00	0.50	-0.79	-1.060	-0.464
$a24$	technology$\rightarrow \Pi^*$	N	0.00	0.50	0.18	0.003	0.415
$a31$	$Y^*\rightarrow R^*$	N	0.00	0.50	0.03	0.009	0.057
$a32$	$\Pi^*\rightarrow R^*$	N	0.00	0.50	0.14	0.067	0.207
$a34$	tech.$\rightarrow R^*$	N	0.00	0.50	0.08	0.027	0.148
$c21$	$Y^*\rightarrow$ technology	N	0.00	0.50	0.25	0.171	0.335
$c31$	$Y^*\rightarrow$ technology	N	0.00	0.50	0.12	0.100	0.147
$c32$	$\Pi^*\rightarrow$ technology	N	0.00	0.50	-0.005	-0.210	0.162
$c24$	technology $\rightarrow \Pi^*$	N	0.00	0.50	-0.02	-0.329	0.287
$c34$	technology $\rightarrow R^*$	N	0.00	0.50	0.06	-0.019	0.127
	Labor market						
ν^j	working capital share	β	0.42	0.15	0.38	0.207	0.542
F,%	endogenous separation SS rate	β	0.18	0.05	0.19	0.164	0.213
recshare, %	SS share of recruitment costs in GDP	Γ	0.31	0.075	0.37	0.345	0.393
σ^L	inverse Frisch labor supply elasticity	Γ	0.74	0.20	0.93	0.859	0.990

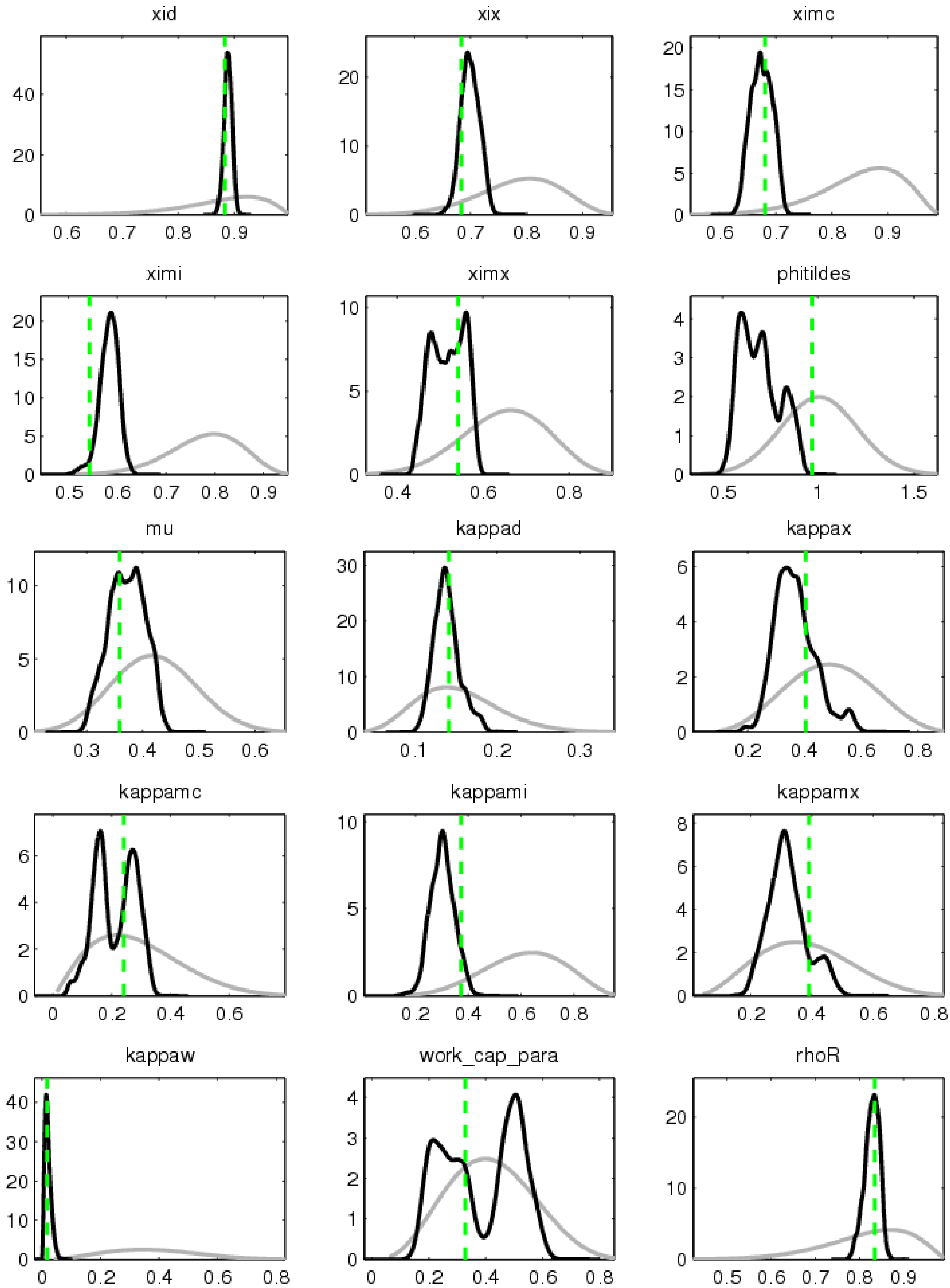
Table B2: List of Priors and Posteriors - continued

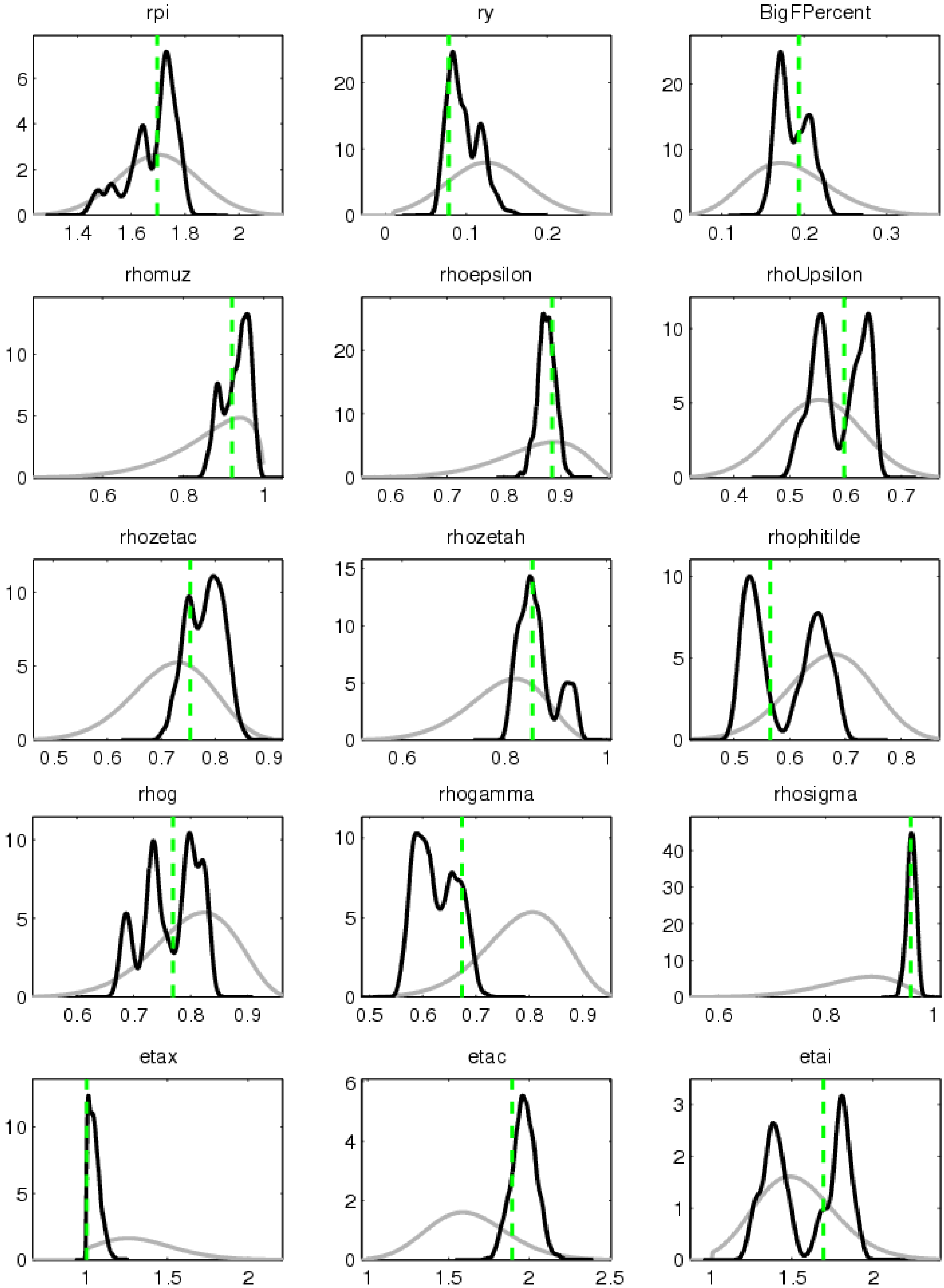
Parameter	Interpretation	Distr.	Prior mean	Prior std	Posterior mean	Posterior 5%	Posterior 95%
	Functional shape parameters						
σ^a	capital utilization	Γ	0.12	0.075	0.10	0.065	0.132
S''	investment adjustment cost	Γ	0.20	0.15	0.21	0.169	0.256
	Other						
$\tilde{\phi}^s$	weight of interest rate differential in risk premium	N	1.005	0.20	0.69	0.576	0.851
μ	monitoring costs	β	0.42	0.075	0.37	0.329	0.414

Table B3: Adopted Naming Convention in Figure B1

Parameter	Dynare Name	Parameter	Dynare Name	Parameter	Dynare Name
ξ_d	xid	r^π	rpi	η^c	etac
ξ_x	xix	r^y	ry	η^i	etai
ξ_{mc}	ximc	ρ^{μ_z}	rhomuz	η^f	etaf
ξ_{mi}	ximi	ρ^ε	rhoepsilon	ν^j	work_cap_para
ξ_{mx}	ximx	ρ^Υ	rhoUpsilon	F ,%	BigFPercent
κ^d	kappad	ρ^{ς_c}	rhozetac	recshare, %	recruitsharePercent
κ^x	kappax	ρ^{ς_h}	rhozetah	σ^L	sigmaLscaled
κ^{mc}	kappamc	$\rho^{\tilde{\phi}}$	rhophitilde	σ^a	sigmaa
κ^{mi}	kappami	ρ^g	rhog	S''	SppScaled
κ^{mx}	kappamx	ρ^γ	rhogamma	$\tilde{\phi}^s$	phitildes
κ^w	kappaw	ρ^σ	rhosigma	μ	mu
ρ^R	rhoR	η^x	etax		

Figure B1: Comparison of Prior and Posterior Distributions




rpi
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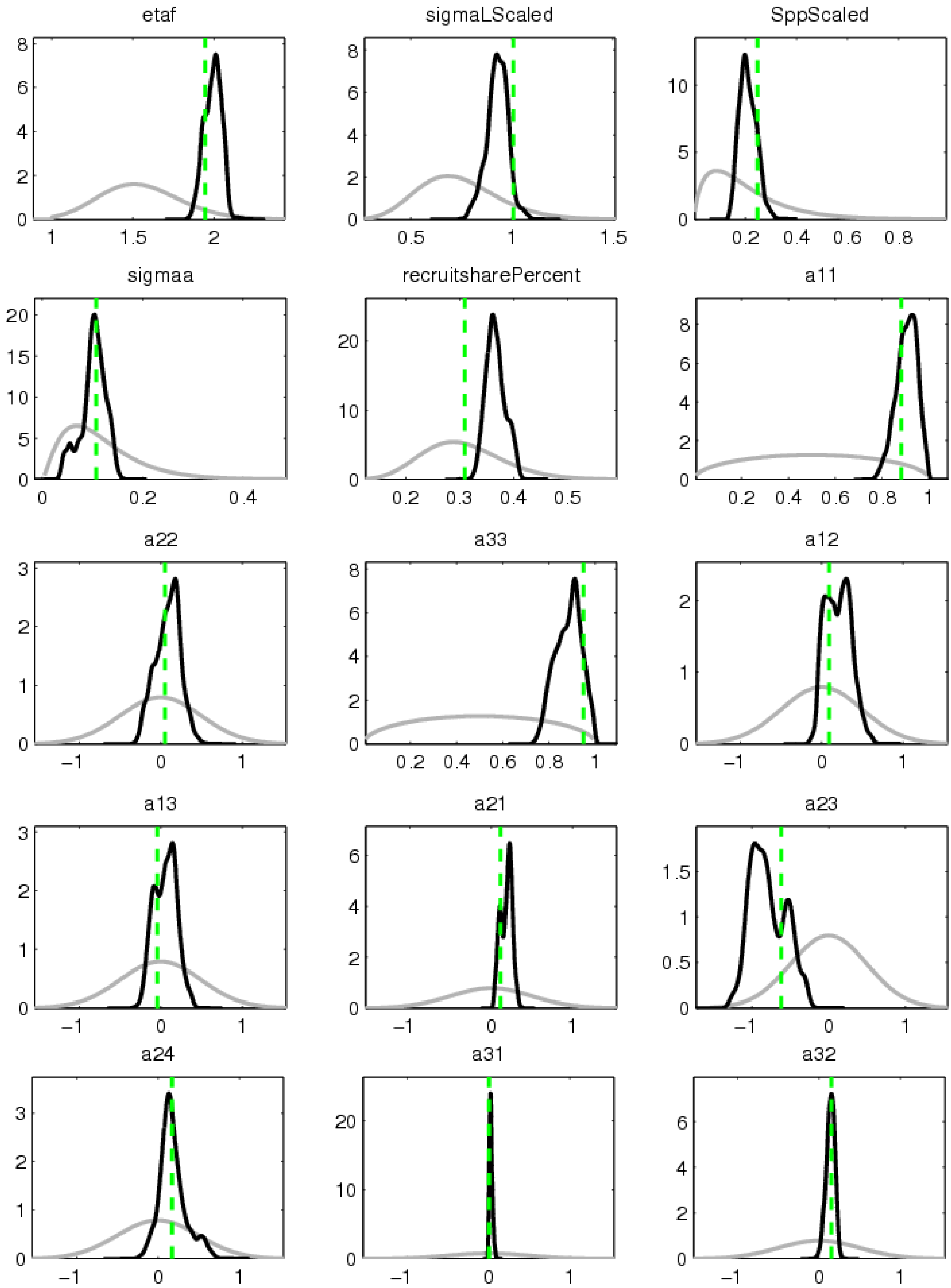
etaf
sigmaLScaled
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a11
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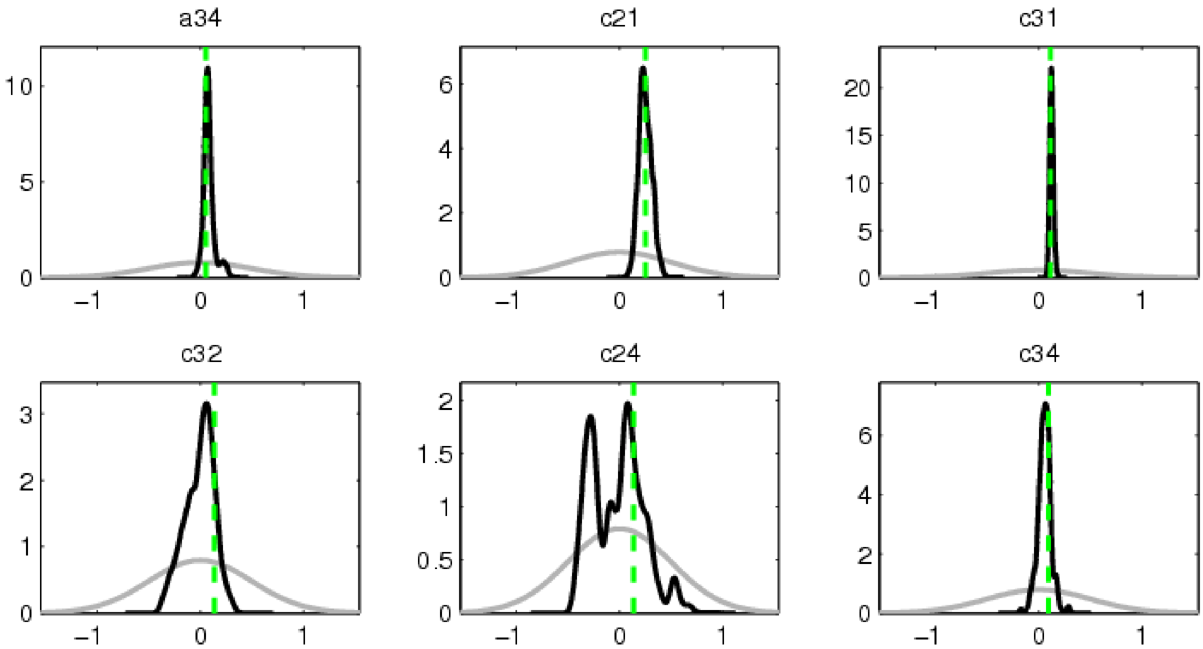
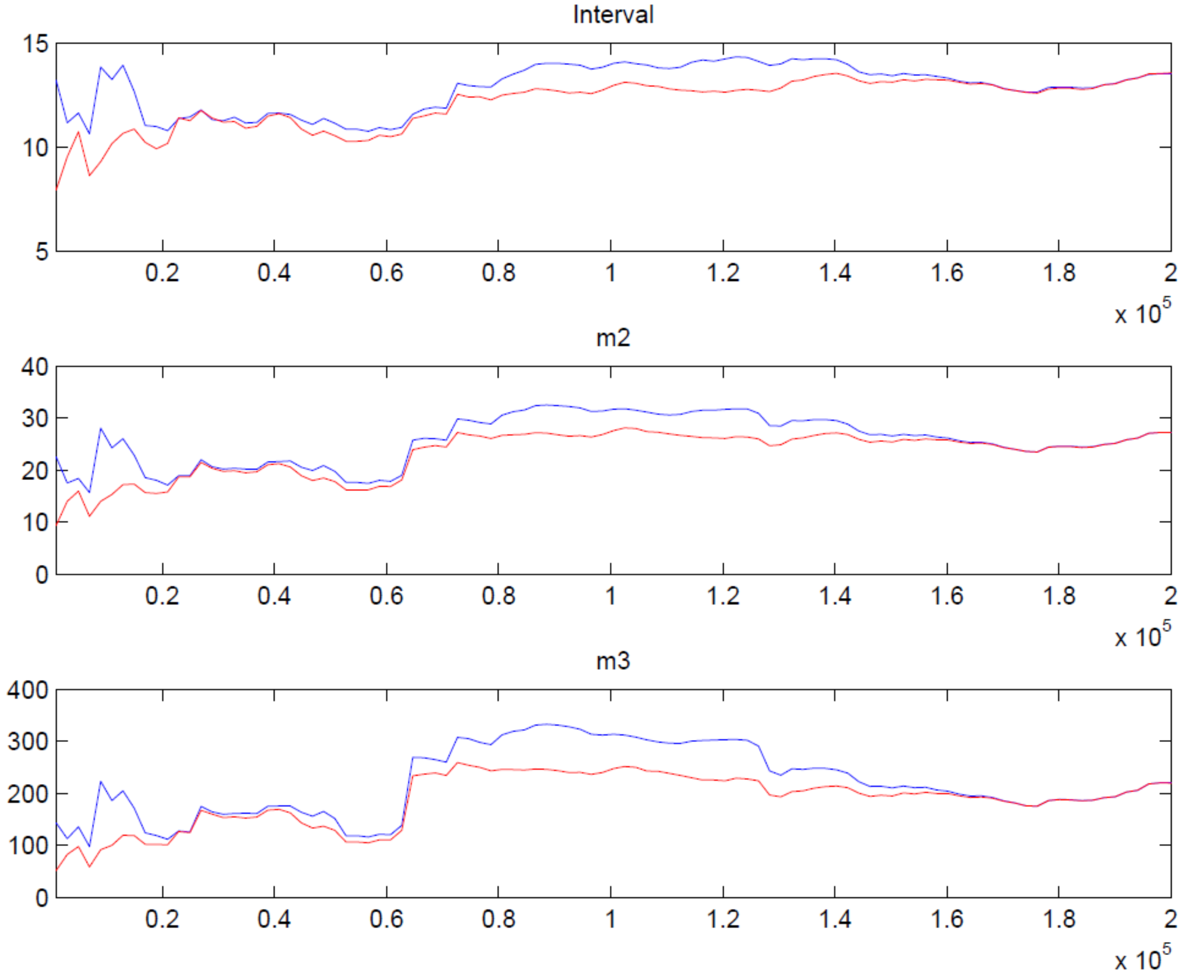
a32



a34
c21
c31
c32
c24
c34

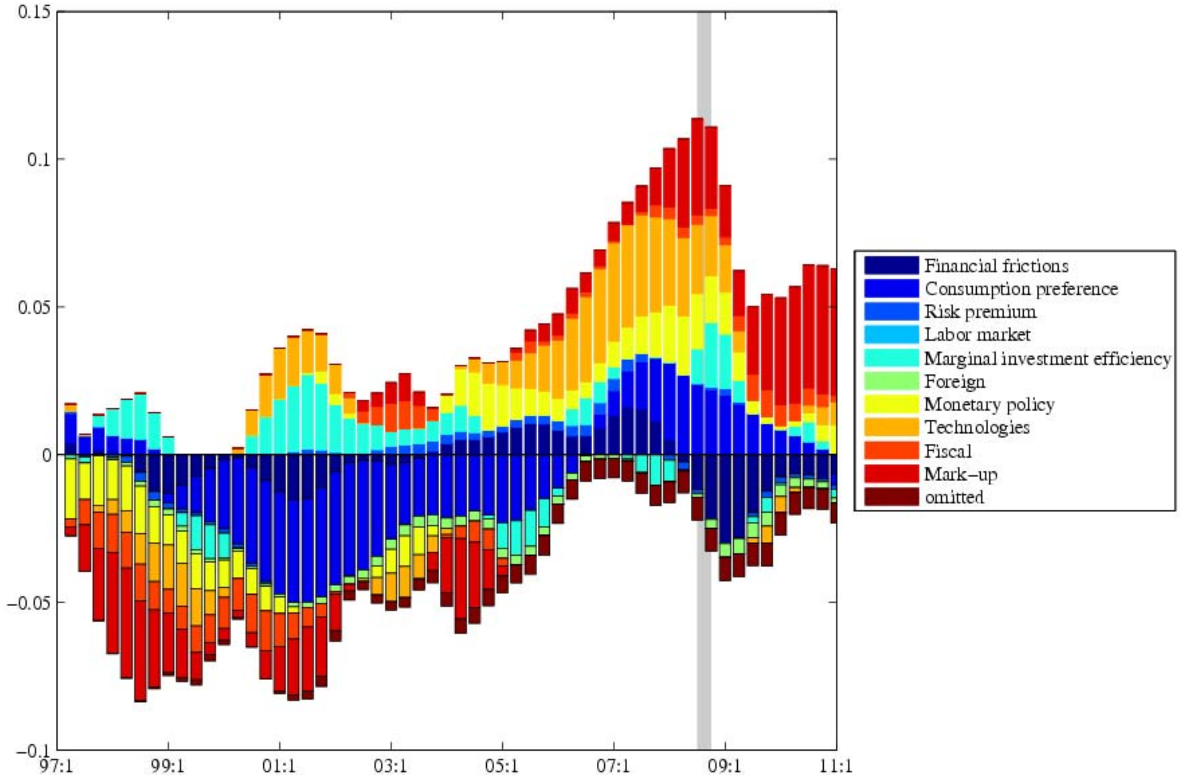
Appendix C: Convergence Statistics

Figure C1: Multivariate Convergence Statistics Based on 500,000 MH Draws, 2 Parallel MH Blocks



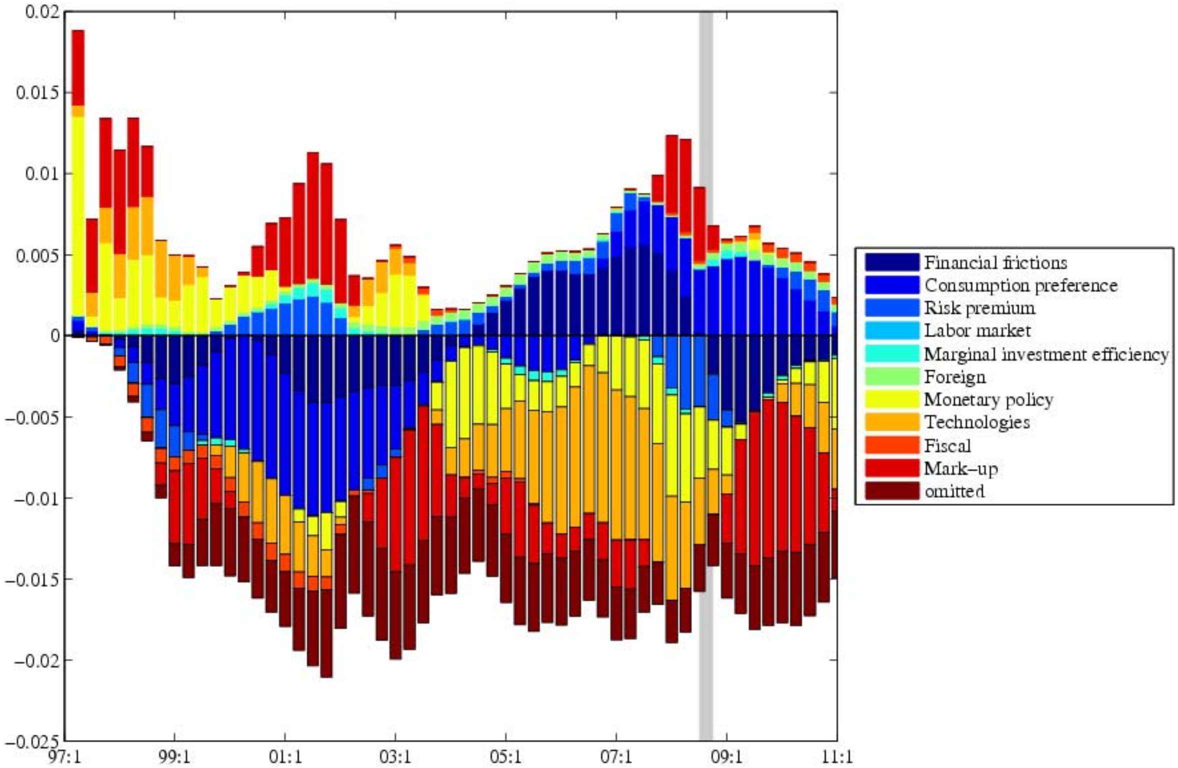
Appendix D: Shock Decomposition

Figure D1: Output Gap



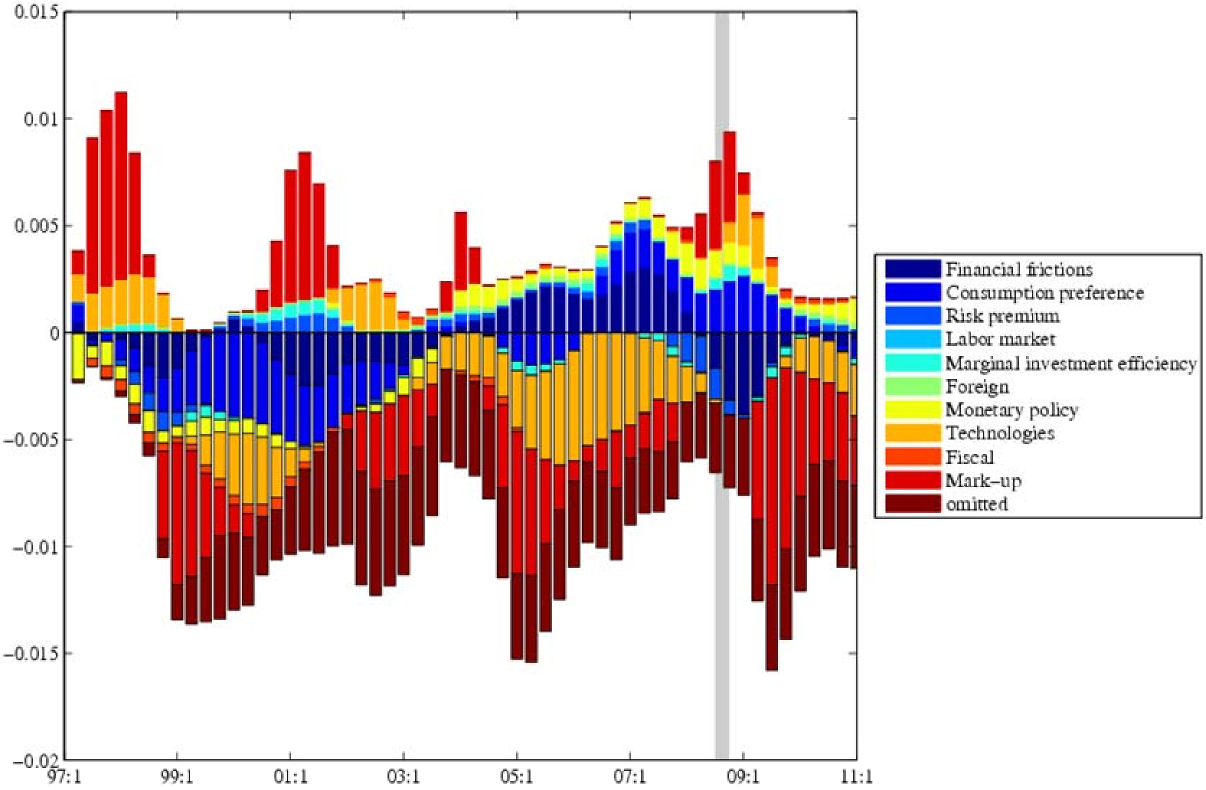
Note: Shaded grey stripes in the graphs mark the beginning of the economic downturn in the Czech Republic due to financial distress – 2008Q4.

Figure D2: Gap of Nominal Interest Rate



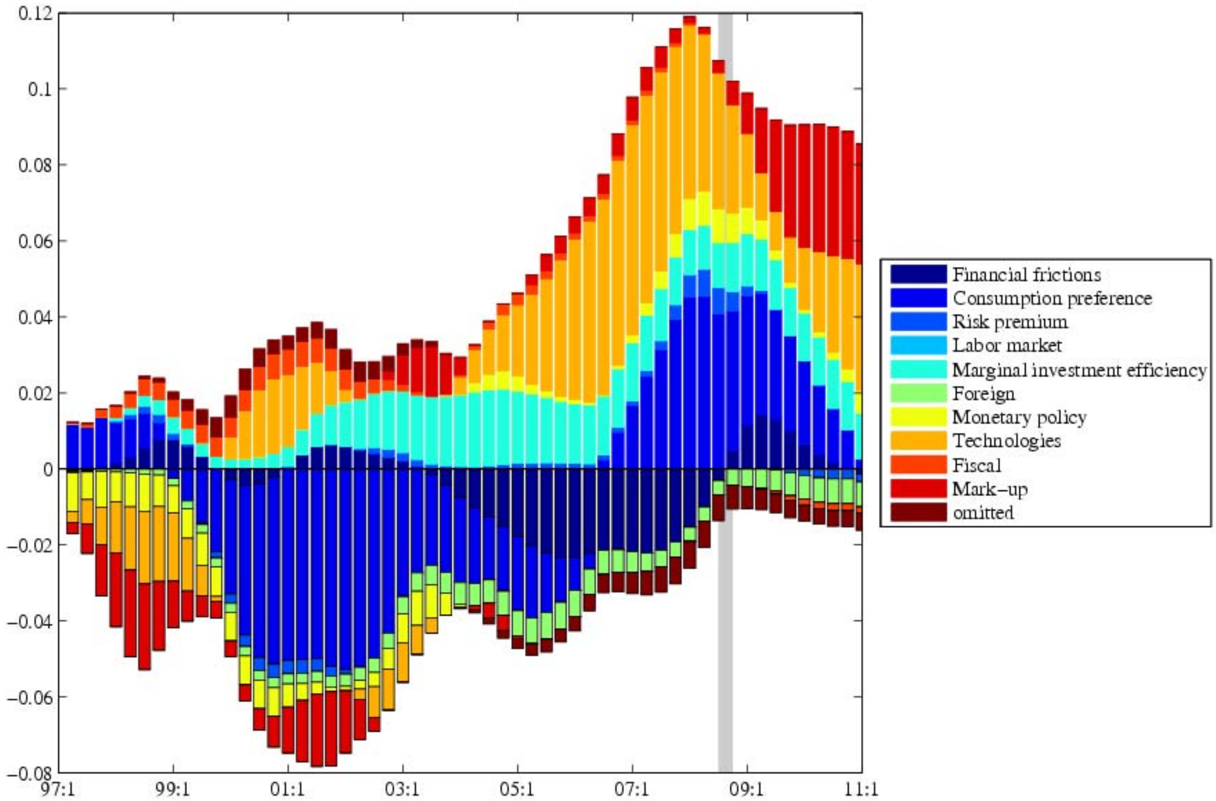
Note: See Figure D1.

Figure D3: Inflation



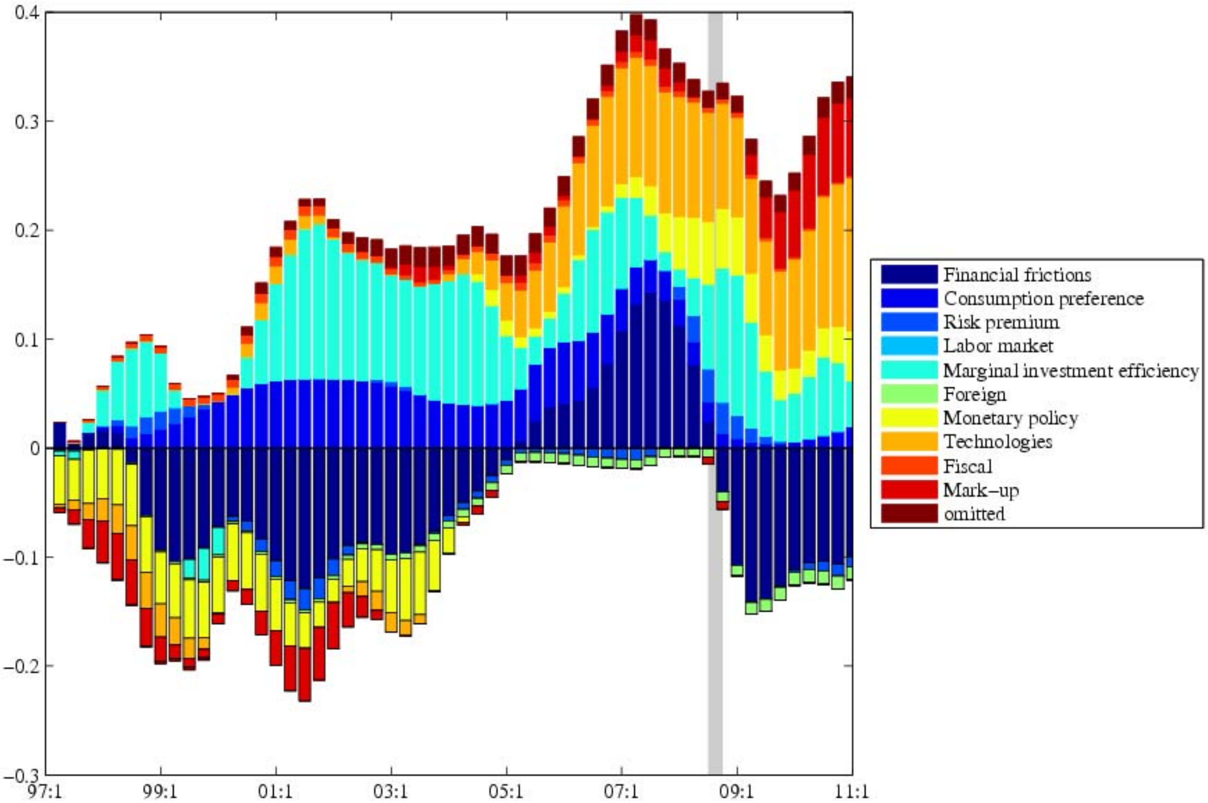
Note: See Figure D1.

Figure D4: Consumption



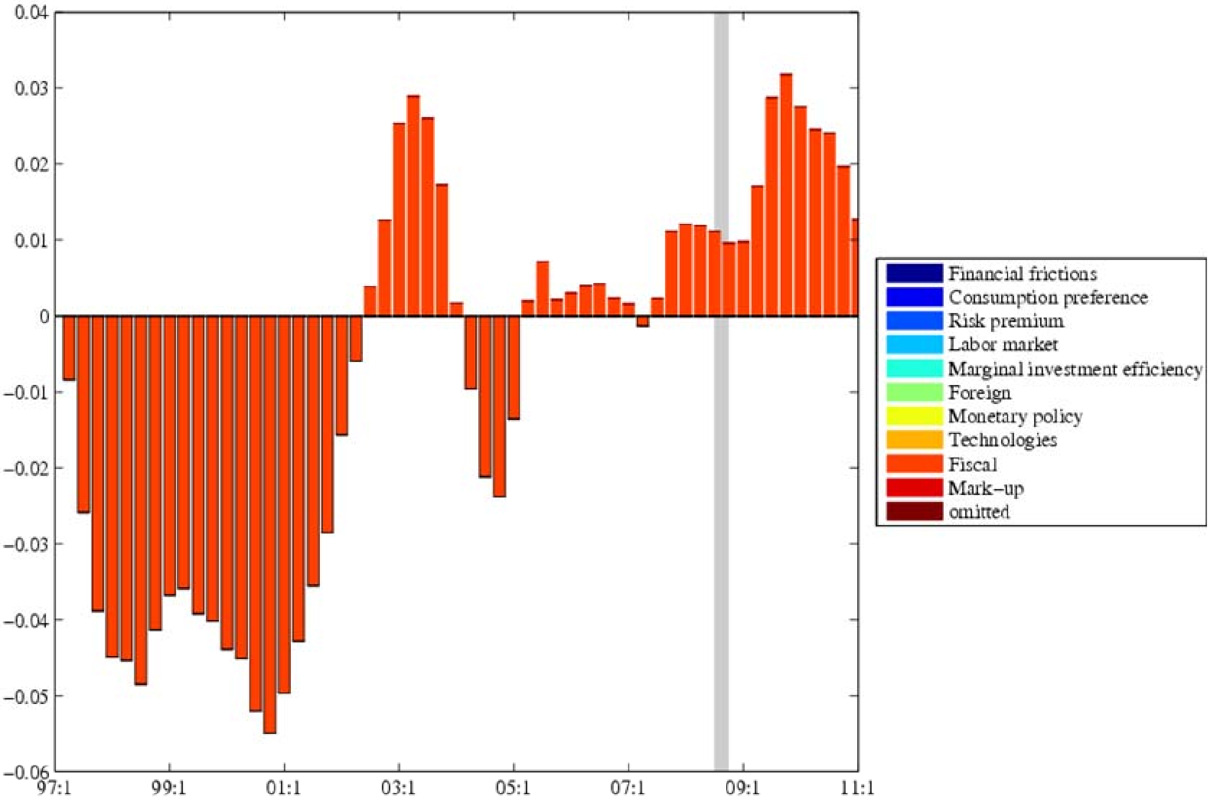
Note: See Figure D1.

Figure D5: Investment



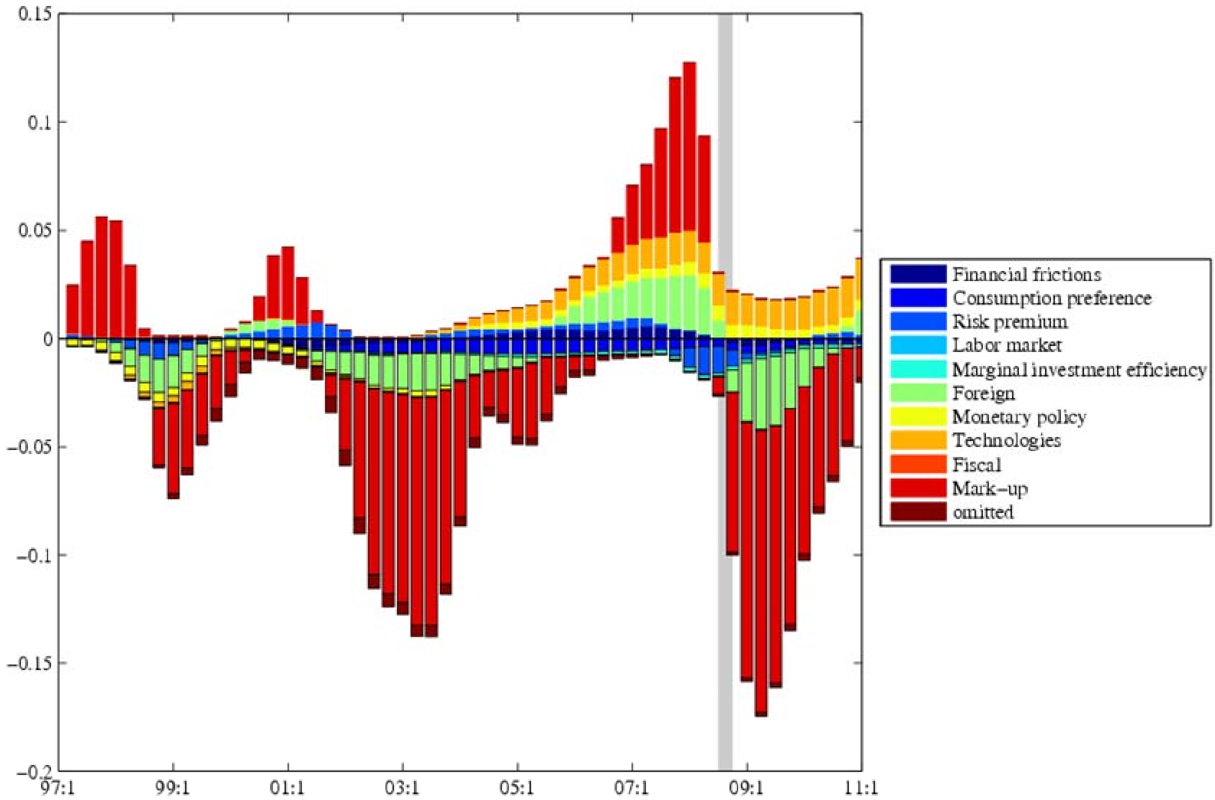
Note: See Figure D1.

Figure D6: Government



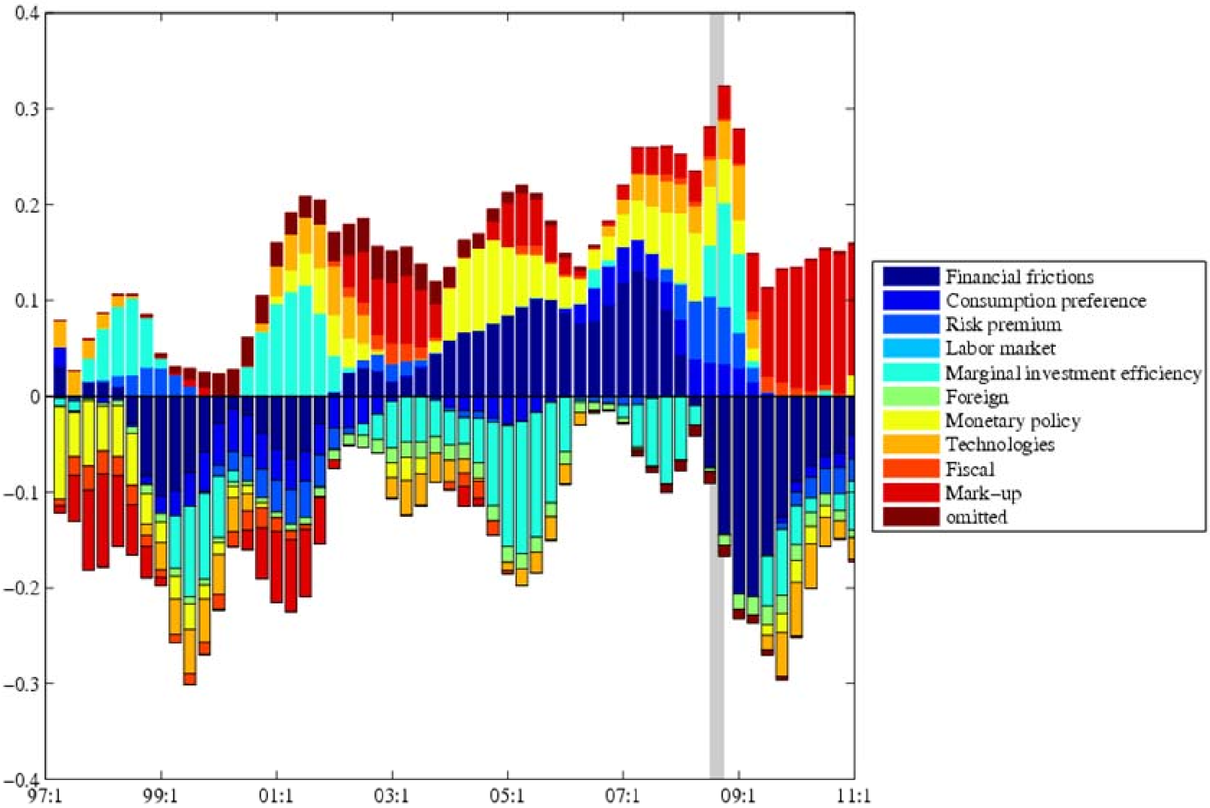
Note: See Figure D1.

Figure D7: Exports



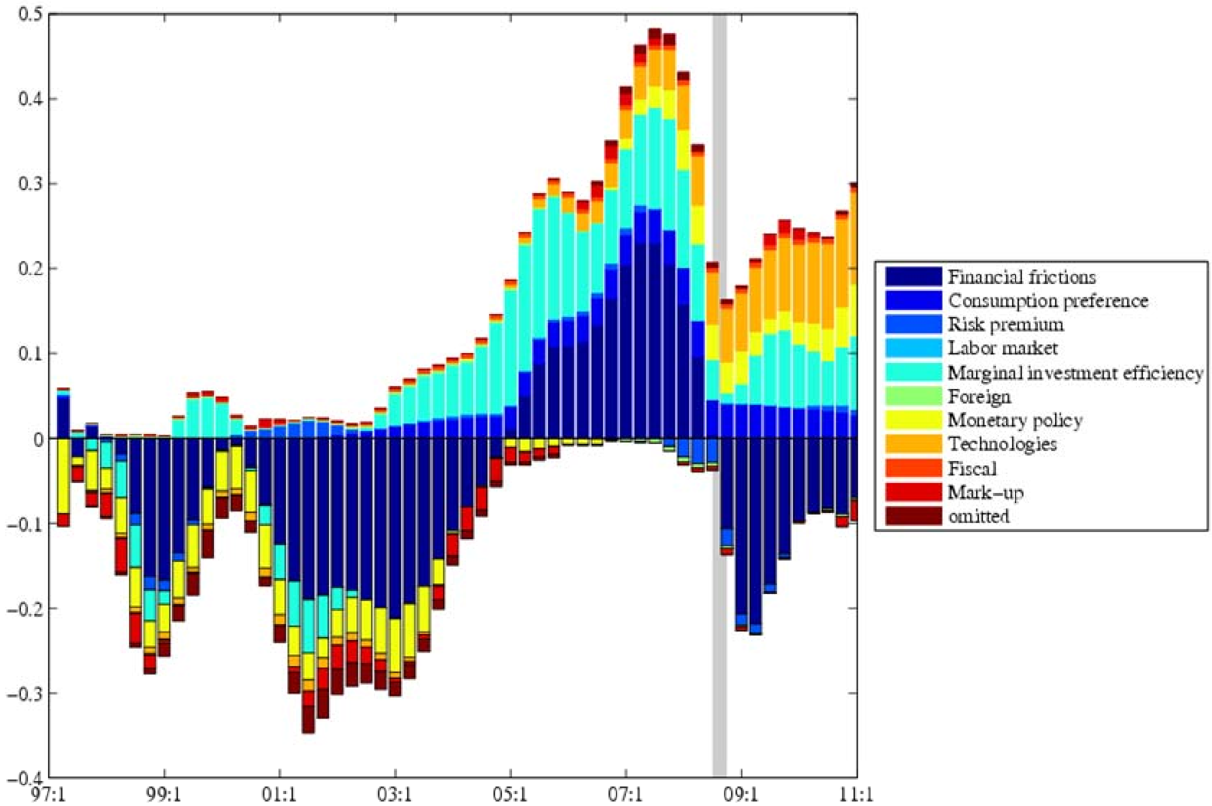
Note: See Figure D1.

Figure D8: Imports



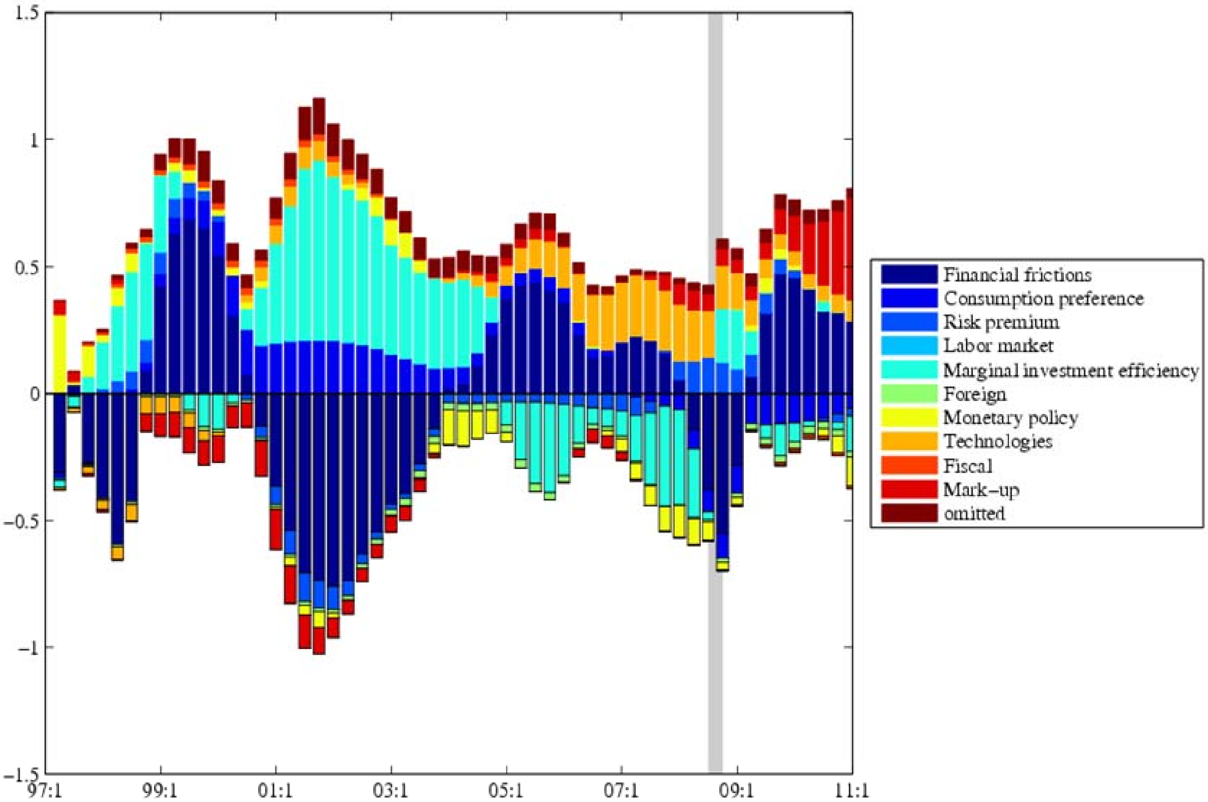
Note: See Figure D1.

Figure D9: Net Worth



Note: See Figure D1.

Figure D10: Spread



Note: See Figure D1.

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Czech National Bank
Economic Research Department
Na Příkopě 28, 115 03 Praha 1
Czech Republic
phone: +420 2 244 12 321
fax: +420 2 244 14 278
http://www.cnb.cz
e-mail: research@cnb.cz
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